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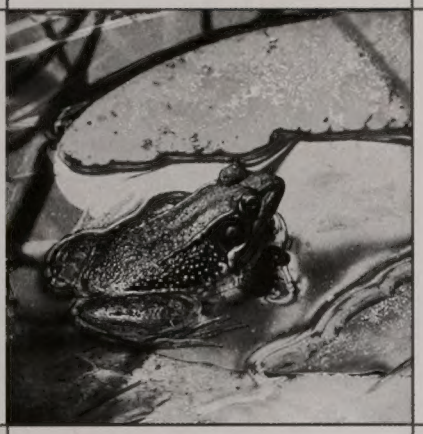

The Changing Illinois Environment: Critical Trends

Technical Report of the Critical Trends Assessment Project Volume 3: Ecological Resources

ENR
Illinois Department of Energy and Natural Resources

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Technical Report of the Critical Trends Assessment Project Volume 3: Ecological Resources

Illinois Department of Energy and Natural Resources
Illinois Natural History Survey Division
607 East Peabody Drive
Champaign, Illinois 61820-6917

June 1994

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Volume 2: Water Resources

Volume 3: Ecological Resources

Volume 4: Earth Resources

Volume 5: Waste Generation and Management

Volume 6: Sources of Environmental Stress

Volume 7: Bibliography

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ABOUT THE CRITICAL TRENDS ASSESSMENT PROJECT

The Critical Trends Assessment Project (CTAP) is an on-going process established to describe changes in ecological conditions in Illinois. The initial two-year effort involved staff of the Illinois Department of Energy and Natural Resources (ENR), including the Office of Research and Planning, the Geological, Natural History and Water surveys and the Hazardous Waste Research and Information Center. They worked with the assistance of the Illinois Environmental Protection Agency and the Illinois departments of Agriculture, Conservation, Mines and Minerals, Nuclear Safety, Public Health, and Transportation (Division of Water Resources), among other agencies.

CTAP investigators adopted a "source-receptor" model as the basis for analysis. Sources were defined as human activities that affect environmental and ecological conditions and were split into categories as follows: manufacturing, transportation, urban dynamics, resource extraction, electricity generation and transmission, and waste systems. Receptors included forests, agro-ecosystems, streams and rivers, lakes, prairies and savannas, wetlands, and human populations.

The results are contained in a seven-volume technical report, *The Changing Illinois Environment: Critical Trends*, consisting of *Volume 1: Air Resources*, *Volume 2: Water Resources*, *Volume 3: Ecological Resources*, *Volume 4: Earth Resources*, *Volume 5: Waste Generation and Management*, *Volume 6: Sources of Environmental Stress*, and *Volume 7: Bibliography*. Volumes 1-6 are synopsized in a summary report.

The next step in the CTAP process is to develop, test, and implement tools to systematically monitor changes in ecological and environmental conditions in Illinois. Given real-world constraints on budgets and human resources, this has to be done in a practical and cost-effective way, using new technologies for monitoring, data collection and assessments.

As part of this effort, CTAP participants have begun to use advanced geographic information systems (GIS) and satellite imagery to map changes in Illinois' ecosystems and to develop ecological indicators (similar in concept to economic indicators) that can be evaluated for their use in long-term monitoring. The intent is to recruit, train, and organize networks of people — high school science classes, citizen volunteer groups — to supplement scientific data collection to help gauge trends in ecological conditions.

Many of the databases developed during the project are available to the public as either spreadsheet files or ARC-INFO files. Individuals who wish to obtain additional information or participate in CTAP programs may call 217/785-0138, TDD customers may call 217/785-0211, or persons may write:

Critical Trends Assessment Project
Office of Research and Planning
Illinois Department of Energy and Natural Resources
325 West Adams Street, Room 300
Springfield, IL 62704-1892

Copies of the summary report and volumes 1-7 of the technical report are available from the ENR Clearinghouse at 1/800/252-8955. TDD customers call 1/800/526-0844, the Illinois Relay Center. CTAP information and forum discussions can also be accessed electronically at 1/800/528-5486.

FOREWORD

"If we could first know where we are
and whither we are tending,
we could better judge what we do
and how to do it..."
Abraham Lincoln

Imagine that we knew nothing about the size, direction, and composition of our economy. We would each know a little, i.e., what was happening to us directly, but none of us would know much about the broader trends in the economy — the level or rate of housing starts, interest rates, retail sales, trade deficits, or unemployment rates. We might react to things that happened to us directly, or react to events that we had heard about — events that may or may not have actually occurred.

Fortunately, the information base on economic trends is extensive, is updated regularly, and is easily accessible. Designed to describe the condition of the economy and how it is changing, the information base provides the foundation for both economic policy and personal finance decisions. Typical economic decisions are all framed by empirical knowledge about what is happening in the general economy. Without it, we would have no rational way of timing these decisions and no way of judging whether they were correct relative to trends in the general economy.

Unfortunately, this is not the case with regard to changes in environmental conditions. Environmental data has generally been collected for regulatory and management purposes, using information systems designed to answer very site-, pollutant-, or species-specific questions. This effort has been essential in achieving the many pollution control successes of the last generation. However, it does not provide a systematic, empirical database similar to the economic database which describes trends in the general environment and provides a foundation for both environmental policy and, perhaps more importantly, personal decisions. The Critical Trends Assessment Project (CTAP) is designed to begin developing such a database.

As a first step, CTAP investigators inventoried existing data to determine what is known and not known about historical ecological conditions and to identify meaningful trends. Three general conclusions can be drawn from CTAP's initial investigations:

Conclusion No. 1: The emission and discharge of regulated pollutants over the past 20 years has declined, in some cases dramatically. Among the findings:

- Between 1973 and 1989, air emissions of particulate matter from manufacturing have dropped 87%, those of sulfur oxides 67%, nitrogen oxides 69%, hydrocarbons 45%, and carbon monoxide 59%.
- Emissions from cars and light trucks of both carbon monoxide and volatile organic compounds were down 47% in 1991 from 1973 levels.
- Lead concentrations were down substantially in all areas of the state over the 1978-1990 period, reflecting the phase-out of leaded gasoline.
- From 1987 to 1992, major municipal sewage treatment facilities showed reductions in loading of biological/carbonaceous oxygen demand, ammonia, total suspended solids and chlorine residuals that ranged from 25 to 72%.
- Emissions into streams of chromium, copper, cyanide, and phenols from major non-municipal manufacturing and utility facilities (most of them industrial) also showed declines over the years 1987-1992 ranging from 37% to 53%.

Conclusion No. 2: Existing data suggest that the condition of natural ecosystems in Illinois is rapidly declining as a result of fragmentation and continual stress. Among the findings:

- Forest fragmentation has reduced the ability of Illinois forests to maintain biological integrity. In one Illinois forest, neotropical migrant birds that once accounted for more than 75% of breeding birds now make up less than half those numbers.

- In the past century, one in seven native fish species in Lake Michigan was either extirpated or suffered severe population crashes and exotics have assumed the roles of major predators and major forage species.

- Four of five of the state's prairie remnants are smaller than ten acres and one in three is smaller than one acre — too small to function as self-sustaining ecosystems.

- Long-term records of mussel populations for four rivers in east central Illinois reveal large reductions in numbers of all species over the last 40 years, apparently as suitable habitat was lost to siltation and other changes.

- Exotic species invasions of Illinois forests are increasing in severity and scope.

Conclusion No. 3: Data designed to monitor compliance with environmental regulations or the status of individual species are not sufficient to assess ecosystem health statewide. Among the findings:

- Researchers must describe the spatial contours of air pollutant concentrations statewide using a limited number of sampling sites concentrated in Chicago and the East St. Louis metro area.

- Much more research is needed on the ecology of large rivers, in particular the effects of human manipulation.

- The length of Illinois' longest stream gaging records is generally not sufficient to identify fluctuations that recur less frequently than every few decades.

- The Sediment Benchmark Network was set up in 1981 with some 120 instream sediment data stations; by 1990 the network had shrunk to 40 stations, the majority of which have data for only one to three years.

CTAP is designed to begin to help address the complex problems Illinois faces in making environmental policy on a sound ecosystem basis. The next edition of the Critical Trends Assessment Project, two years hence, should have more answers about trends in Illinois' environmental and ecological conditions to help determine an effective and economical environmental policy for Illinois.

VOLUME SUMMARY

The Illinois Natural History Survey's contribution to the Critical Trends Assessment Project is in seven sections, here bound in one volume. The first six sections cover six ecosystem types: prairies, forests, agricultural lands, wetlands, lakes and impoundments, and flowing waters. The seventh covers resource issues. For each section there is a summary of one or two pages.

To summarize the summaries: Although we lack an overall metric of ecosystem health, Illinois ecosystems are greatly affected by human activity, and that effect in general seems to be increasing. This is in spite of many specific improvements and an overall reduction in pollution sources. Often the largest impact is land use, the weight of many pressures on few acres.

Prairies. The Illinois tallgrass prairie, which originally covered 60% of the state, is 99.99% gone.

Forests. Originally diminished by development, forests are coming back; forest biomass is accumulating. Forests are repositories for many threatened species. Even with increased standing timber, however, biodiversity is threatened by increased forest fragmentation and by exotic species.

Agricultural Lands. Eighty percent of the state is farmland. Intensive monoculture has impoverished ecosystems and affected streams. Some improvement is now occurring; erosion rates are diminishing, for example.

Wetlands. Illinois was originally 25% wetlands. It is now 3% wetlands, with only 0.016% classified as approaching pristine. Wetlands are also repositories of endangered and threatened species.

Lakes and Impoundments. Except for Lake Michigan and a few lakes in northern Illinois, essentially all lakes in Illinois are artificial. Lake Michigan fish species have been significantly affected by introduced exotics and fishing pressure. Impoundments are seriously affected by stream sedimentation and eutrophication, both products of activities in the surrounding watershed.

Flowing Waters. Water quality has historically deteriorated, leading to the extirpation and threatened extirpation of many species (19–55%) of fish, amphibians and reptiles, mussels, and crayfish. Recently there has been environmental improvement in large rivers (Mississippi and Illinois) because of reduced point-source pollution (e.g., sewage). However, there are persistent and serious sedimentation and chemical problems, which again reflect activities in the watersheds.

Resource Analysis. A broad indicator of overall environmental impact is the ratio of fossil fuel consumption (including consumption by nuclear power plants) to solar radiation. In Illinois this averages 0.06, which is 600 times the world average, seven times China's average, and about half of Germany's average. In Chicago the ratio is approximately one. Illinois has much coal, but the state could not be self-sufficient for more than 10 months in its use of oil or for more than a few weeks in its use of natural gas. Soil erosion is diminishing, and even at today's rate of erosion topsoil will last several hundred years on average. There is wide variation in this lifetime from county to county.

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PRAIRIES

SUMMARY

Grasslands are biological communities in which the landscape is dominated by herbaceous vegetation, especially grasses; they contain few trees or shrubs. Approximately 32 to 40% of the world's land surface is, or was, covered by grasslands. In North America, grasslands are the largest vegetation type, covering approximately 15% of the land area. The most abundant grasslands in North America are prairies.

Illinois lies within an eastward extension of the tallgrass prairie called the prairie peninsula. Before people of European descent settled in the region, this prairie extension was bounded on the north, east, and south by deciduous forests. At one time, Illinois, the Prairie State, was about 60% prairie, found mainly in the northern two-thirds of the state. Forests were generally restricted to stream banks and the northwestern and southern portions of Illinois.

In an astonishingly short period, roughly between 1840 and 1900, a vast amount of tallgrass prairie was destroyed. The Illinois Natural Areas Inventory has concluded that only 1/100 of 1% of the original prairie remains, with only 2,352 acres of high-quality prairie remaining. High-quality (grade A and B) prairie remnants tend to be found in very small patches. Of the 253 prairie sites identified by the Illinois Natural Areas Inventory, 83% are smaller than 10 acres and 30% are less than 1 acre! These remaining prairie sites are found primarily along the northern and western edge of Illinois. The once vast Grand Prairie of central Illinois is all but gone.

Currently, only 6% of the natural areas listed on the Illinois Natural Areas Inventory are afforded maximum protection against future changes in land use as dedicated Illinois Nature Preserves. Seventy-eight percent of Illinois prairie areas are classified as unprotected. The threats to these unprotected areas are numerous and include building and highway construction, railroad maintenance, grazing, and cemetery mowing. Seventy-three percent of these prairie areas are likely to experience major threats within five years, and 9% are in immediate danger.

The best examples of prairies in imminent danger are the hill prairies of Illinois. Although hill prairies were once thought to be among the more secure prairie types because their soils are poorly suited for plowing, a century of neglect is jeopardizing these remnant prairie sites. Invasion by woody species has reduced the size of Illinois hill prairies by an average of 50% during the past 50 years. This trend continues into the 1990s. Sparse biological data indicate that this loss in area has been accompanied by a loss in the biological diversity of hill prairie species during this period.

Because of their small sizes and fragmented nature, Illinois' remnants of the tallgrass prairie lack the full complement of natural processes that operate at large ecological scales. Prairies developed and were maintained under the influence of three major abiotic factors: climate, grazing, and fire (Anderson 1982). Natural processes such as landscape-scale fires and grazing by large native mammals are no longer natural components of Illinois prairie. In addition, human land use has led to ecosystem changes other than outright habitat loss and fragmentation that threaten the biological integrity of some sites. These changes include drainage of surrounding agricultural lands, the input of pollutants (perhaps most importantly, nitrogenous pollutants), climate change, and the introduction of cattle and numerous other non-native plants and animals. Without detailed studies of the direct effects of these changes, however, it will be difficult to assess their effects in any specific manner.

With such dramatic changes to Illinois prairies, we do not expect them to function as natural ecosystems. Nonetheless, they represent a major component of our natural heritage and provide habitat for numerous plant and animal species that could not otherwise exist in Illinois. The tallgrass prairie has been called "the most diverse repository of species in the Midwest [and] . . . habitat for some of the Midwest's rarest species" (Chapman et al. 1990). With respect to plants, it appears that most remnant prairie sites are so small that there is a high potential for future species loss. At present, most true prairie species are found on relatively few sites. Unfortunately, few sites have undergone repeated surveys to document whether our prairie sites are losing diversity. However, both plant and animal evidence suggests that most of our small prairie preserves provide refuge for only a small subset of the total biological diversity that may be found locally.

Thus, it is vital that remaining unprotected sites become protected to ensure against further species loss.

Birds are probably the most studied group of organisms on prairies. Several Illinois bird population studies, beginning in the mid-1800s and continuing through 1989, have provided insight into population trends. A long trend in decreasing abundance of nearly all grassland birds is continuing through to the present. This decline is exemplified by the prairie-chicken, a once common bird in Illinois that is now on the verge of extirpation within the state.

Several thousand species of insects must have originally inhabited the vast Illinois prairie. Fortunately, most seem to have survived the near total destruction of their pre–European settlement habitats. A majority of these animals inhabit a variety of humanized habitats, such as pastures, hayfields, parks, yards, and fencerows. Isolated populations of prairie-dependent insects on small, widely scattered prairie remnants contend with excessive edge effects and the high extinction rates associated with island-dwelling organisms. Having lost more than 99.99% of their presettlement habitats, this group of remnant-requiring animals is clearly vulnerable to the ongoing alteration of the Illinois landscape. Studies are currently under way to address the issue of insect persistence on prairie remnants.

A number of prairie species (five mammals, four birds, three insects, five plants) have been extirpated from Illinois within historic time. Additional species (117) have become so rare that they are listed as endangered or threatened. Finally, the numbers of individuals of the surviving prairie species are very small compared to the numbers living in 1820, although no precise figures are available. This poses a serious threat with respect to vulnerability to extinction through chance events, as well as vulnerability to genetic problems associated with small population sizes, although little direct evidence to address this issue has been collected.

Another consideration is that about 27.5% of the vascular plants growing spontaneously in Illinois are not native. These pose serious threats to the continued existence of the native flora and fauna of prairies. Reports of weedy plant, noxious insect, and mammalian pests are increasing in all habitats throughout the United States. Illinois prairies are no exception. We are dedicating more and more of our management time and resources in an effort to control species invading and degrading our prairie habitats. This issue will continue to be the primary threat to Illinois prairies through the remainder of the 20th century.

GENERAL DESCRIPTION

Grasslands are biological communities in which the landscape is dominated by herbaceous vegetation, especially grasses; they contain few trees or shrubs. Approximately 32 to 40% of the world's land surface is, or was, covered by grasslands (Burton et al 1988, Groombridge 1992). Notable examples include the prairies of North America, the llanos of northern South America, the pampas of Argentina, the steppes of central Asia, the veldt of Africa, and the grasslands of Australia.

Grasslands are the largest vegetation type in North America, covering approximately 15% of the land area, and prairies are the most abundant type of grassland on the continent (Burton et al. 1988). Prairies form a more or less continuous, roughly triangular area that extends from Alberta, Saskatchewan, and Manitoba southward through the Great Plains to southern Texas and adjacent Mexico and from western Indiana westward to the foothills of the Rocky Mountains (Risser et al. 1981; Madson 1982; Farney 1980; Weaver 1954, 1968) (Figure 1). This region is approximately 2,400 miles from north to south and 1,000 miles from east to west, covering 1.4 million square miles.

Because of the rain shadow effect of the Rocky Mountains, which intercepts the eastward flow of moist air from the Pacific Ocean, there is a gradual increase in average annual precipitation from west to east, and this is reflected in the types of prairies found in central North America (King 1981a, b). Precipitation is about 10˝ to 15˝ a year in the western part of the prairie region, and the dominant vegetation is *short-grass prairie*. In the middle of the prairie region, annual rainfall ranges from 15˝ to 25˝, and the *mixed-* or *mid-grass prairie* occurs. Toward the eastern part of the prairie region, rainfall is between 25˝ and 40˝ a year, and this is the domain of the *tallgrass* or *true prairie*. Today, these three prairie types correspond to the rangelands of the Great Plains (short-grass prairie), the wheat belt (mid-grass prairie), and cornbelt (tallgrass prairie). There is also a dramatic decrease in mean annual temperatures from south to north in the prairie region.

Formation of Prairies

Prairies are one of the most recently formed ecosystems in North America (Axelrod 1985). The tallgrass prairie in Illinois was formed following the most recent period of the Pleistocene glaciation. Based on the evidence of fossil pollen grains, prairie first appeared in central Illinois about 8,300 years ago (King 1981a, b).

Prairies developed and were maintained under the influence of three major abiotic factors: climate, grazing, and fire (Anderson 1982, 1991). Occurring primarily in the central part of North America, prairies are subject to extreme ranges of temperatures, with hot summers and cold winters. There are also great fluctuations of temperatures within growing seasons.

Droughts are also characteristic of the climate in the prairie regions. These droughts may last only one or two months or continue for several years. Cyclic droughts also occur every 30 years or so.

Before intervention by humans of European descent, wildfires occurred regularly in the prairie regions. Any given parcel of land probably burned once every one to five years. These fires moved rapidly across the prairie, and damaging heat from the fire did not penetrate the soil to any great extent.

A considerable portion of the aboveground biomass of a prairie was consumed each year by the grazing of a wide range of browsing animals, such as bison, elk, deer, rabbits, and grasshoppers. Prairie plants are adapted to these stresses by largely being herbaceous perennials with underground storage/perennating structures, growing points slightly below ground level, and extensive, deep root systems. The three abiotic factors of climate, grazing, and fire are important to keep in mind when formulating management practices for today's prairie remnants. In later discussions, grazing is mentioned as being a disturbance factor in prairie remnants, but this refers only to grazing by domestic livestock, which has a quite different impact than the free-ranging grazing of native large mammals.

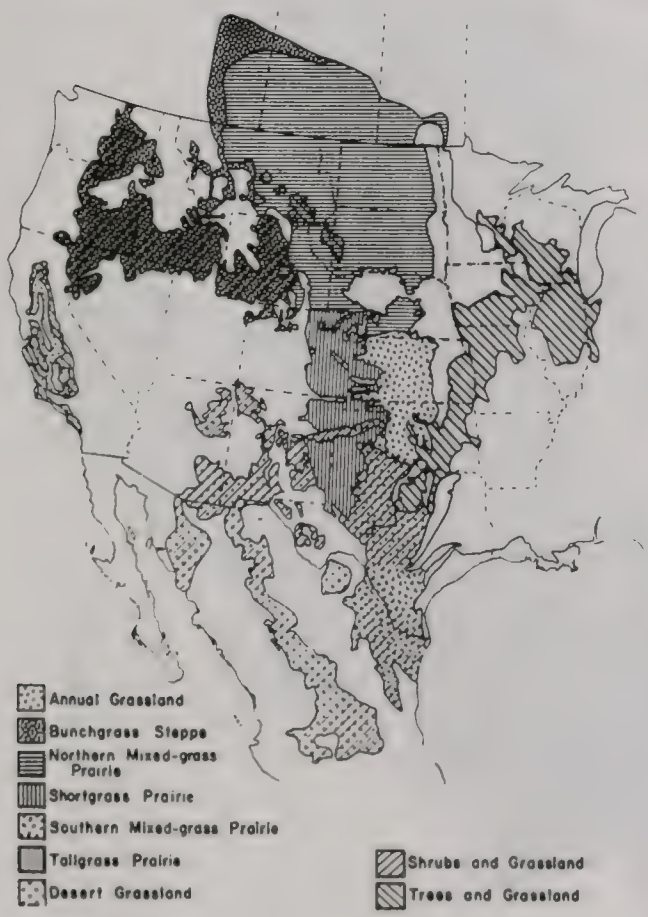

Figure 1. Major grassland types of the United States, Canada, and Mexico (reprinted from Risser et al. 1981).

Prairies are complex ecosystems in which plants, grazing mammals, burrowing animals, insects, fire, and climate interact in balance. In agricultural terms, the tallgrass prairie sustains high productivity while building and maintaining soil (Chapman et al. 1990).

Extent of Original Prairie

Illinois lies within an eastward extension of the tallgrass prairie called the prairie peninsula, which was, before settlement by Europeans, bounded on the north, east, and south by deciduous forests (Transeau 1935). At one time Illinois, the Prairie State, was about 60% prairie, found mainly in the northern two-thirds of the state. Forests were generally restricted to stream banks and the northwestern and southern portion of Illinois.

The extent of Illinois presettlement prairie is well documented. A map was generated from the original government land survey records showing the distribution of forests and prairies in Illinois (Anderson 1970) (Figure 2). This map was digitized by Iverson (1988, 1989), and geographic information system software was used to estimate that in 1820 Illinois had approximately 21.6 million acres of prairie, or about 61.2% of the land area. The estimated amount of prairie that existed in each county in 1820 is shown in Figures 3 and 4; all but nine of the 101 counties in Illinois are shown as having at least some prairie habitat.

Some scientists believe these figures underestimate the extent of prairie in Illinois prior to European settlement. For example, although no prairie acreages are listed by Iverson (1989) for nine counties in southern Illinois, the natural divisions occurring in these counties had at least some small prairie openings (Schwegman 1973). Another uncertainty concerns the recording of savannas on the original land surveys, because savannas have scattered trees with a prairie-like ground cover (Nuzzo 1986).

Figure 2. Distribution of forest and prairie in Illinois about 1820 (adapted from Iverson 1989).

Changes in Land Use of Prairie

In an astonishingly short period, roughly between 1840 and 1900, a vast amount of tallgrass prairie was destroyed. At present, only ⅛₀₀ of 1% of the original prairie remains (Figure 4). The early European settlers, being originally from forested regions in Europe and subsequently eastern North America, found the prairies to be rather frightening due to the hordes of insects, intense summer heat and high humidity, bleak windy winters, and periodic raging prairie fires. Because no trees grew on the prairies, the settlers at first considered the prairies to be unsuitable for crop plants. This, plus the need for construction timber and firewood, prompted the settlers to build their homes at the edges of the prairie, in prairie groves (islands of woods surrounded by prairie), and along wooded streams. It was not long, however, before the settlers discovered that the prairie soil was more fertile than forest soil—actually among the most productive soils in the world (Bogue 1968). A difficulty was that the prairie sod was so dense with tangled roots and deep that available plows were not able to break it easily. Prairie sod could not be broken easily until 1837, when John Deere, living in Grand Detour, Illinois, invented the self-scouring, steel-bladed plow. It can be said that the economic development of Illinois depended on the conversion of prairie soil to agricultural and eventually urban uses. In terms of overall land use, Illinois ranks 49th among the 50 states in the percentage of natural vegetation remaining (Klopatek et al. 1979).

It is impossible to document today exactly how rapidly the prairies were plowed. One estimate is that 3.3% of the prairies in the state were plowed each year (Page

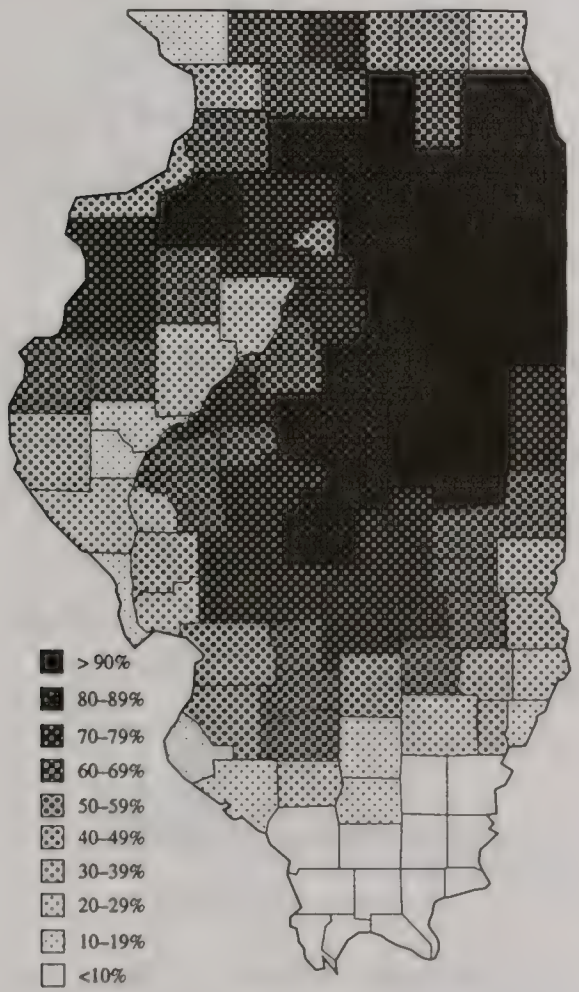

Figure 3. Percentage of each Illinois county that was prairie in 1820 (Source: Iverson 1989).

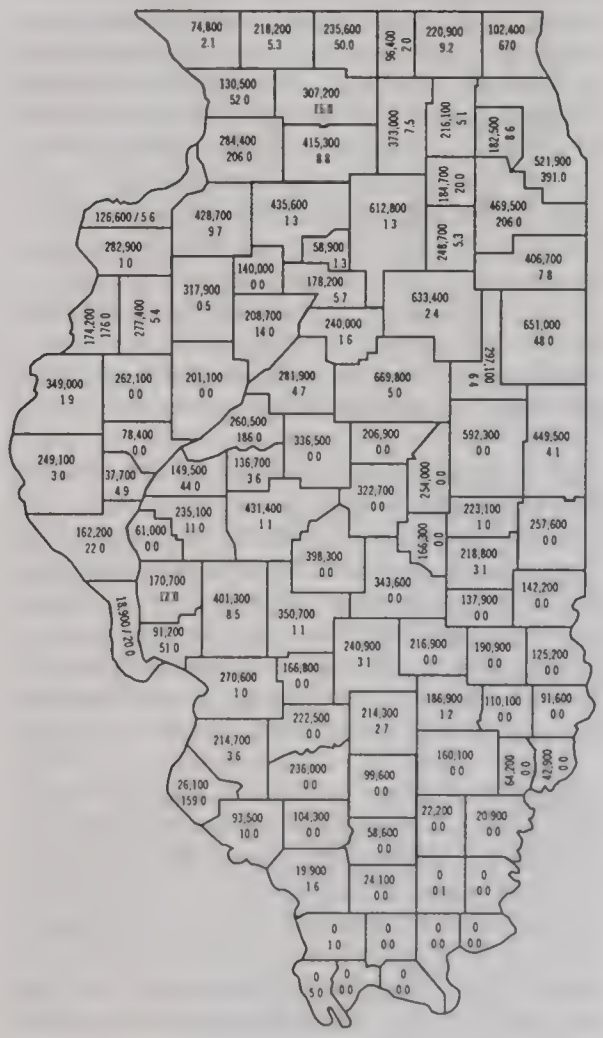

Figure 4. Changes in Illinois prairie acreage by county. The first number is the number of acres of prairie in 1820; the second is the number of acres of high-quality prairie remaining in 1976. Data for 1820 from Iverson (1989); 1976 data from White (1978).

and Jeffords 1991). Only a few contemporary accounts lamented the destruction of the prairies. Robert Ridgway, the noted pioneer of ornithology in Illinois, related that in 1871 Fox Prairie (Richland County) was a large rolling plain of uninterrupted prairie 6 miles broad by 10 miles long but that by 1883 only 160 acres remained, the rest being covered by farms with cottages, fields, and orchards (Ridgway 1889). Herre (1940) wrote that when he returned to Illinois in the 1890s most of the prairies he had seen earlier had disappeared.

ASSESSMENT OF CRITICAL INDICATORS

Habitat

Prairies Remaining in Illinois. In 1976 Illinois Natural Areas Inventory crews searched aerial photographs of each county in Illinois for high-quality natural areas (White 1978); this was followed by field work to examine potential sites. The survey concluded that only 0.01% of the original prairie existed in 1976 (Schwegman 1983). The workers located 253 sites containing 2,352 acres of high-quality prairie (Figure 5). On a statewide basis, it is estimated that 52.9% of the land in Illinois was converted to agricultural land between 1820 and 1980, and 3.1% was converted to urban areas (Iverson 1988). In addition, 2.6% of the land in the state changed from prairie to forest; this was presumably due to the cessation of widespread prairie fires.

Land-use changes have been calculated for two counties in Illinois using geographic information system software (Iverson and Risser 1987). The land in Lake County was originally 29.2% prairie, or 102,400 acres. Of this amount, 65% was converted to agricultural use and 27% to urban use. In Jackson County, prairie originally accounted for only 2% of the land area. Seventy-five percent of this small amount of prairie is now used for agriculture and 6% for urban uses.

Figure 4 shows the number of acres of prairie in each Illinois county in 1820 and the number of acres of high-quality prairie (Illinois Natural Areas Inventory grade A and B) in 1976. Grade A is used for natural communities that have a structure and composition that are stable and that show little or no effect of disturbance by humans. Grade B is used for former grade A communities that have either been lightly disturbed or moderately to heavily disturbed but which have recovered significantly. Not included in the data from which the map was made are the numerous grade C prairies, which have been moderately to severely disturbed to the extent that the original structure was destroyed and the species composition has been changed significantly.

A few examples illustrate these drastic changes in prairies. Cook County had approximately 521,900 acres of prairie in 1820, but only 391 acres of grade A and B prairie remained in 1976. McLean County, which had 669,800 acres, now has only 5 acres. Champaign County, which once had 592,300 acres of prairie, was thought to have none in 1976. Since 1976, however, a 1-acre dry-mesic savanna with mostly prairie vegetation was found in the extreme northeastern part of the county. The Nature Conservancy (Chapman et al. 1990) estimates that more than 99% of the tallgrass prairie east and north of the Missouri River has been destroyed, and only about 15% remains to the west and south of this river.

The remaining high-quality (grade A and B) prairies tend to be found in very small patches (Figure 6). Of

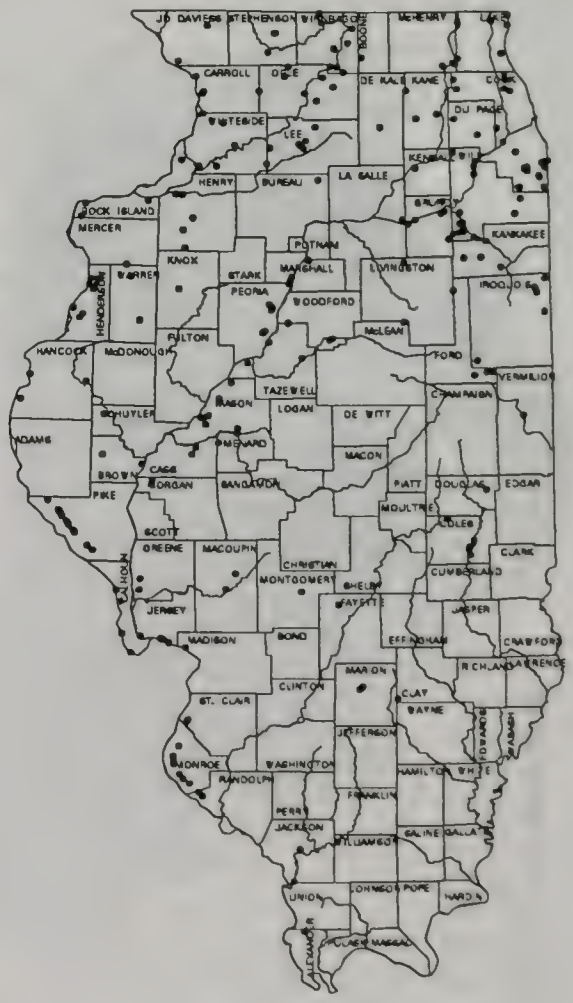

Figure 5. Locations of grade A and B natural areas that contain prairie (Source: Illinois Natural Areas Inventory).

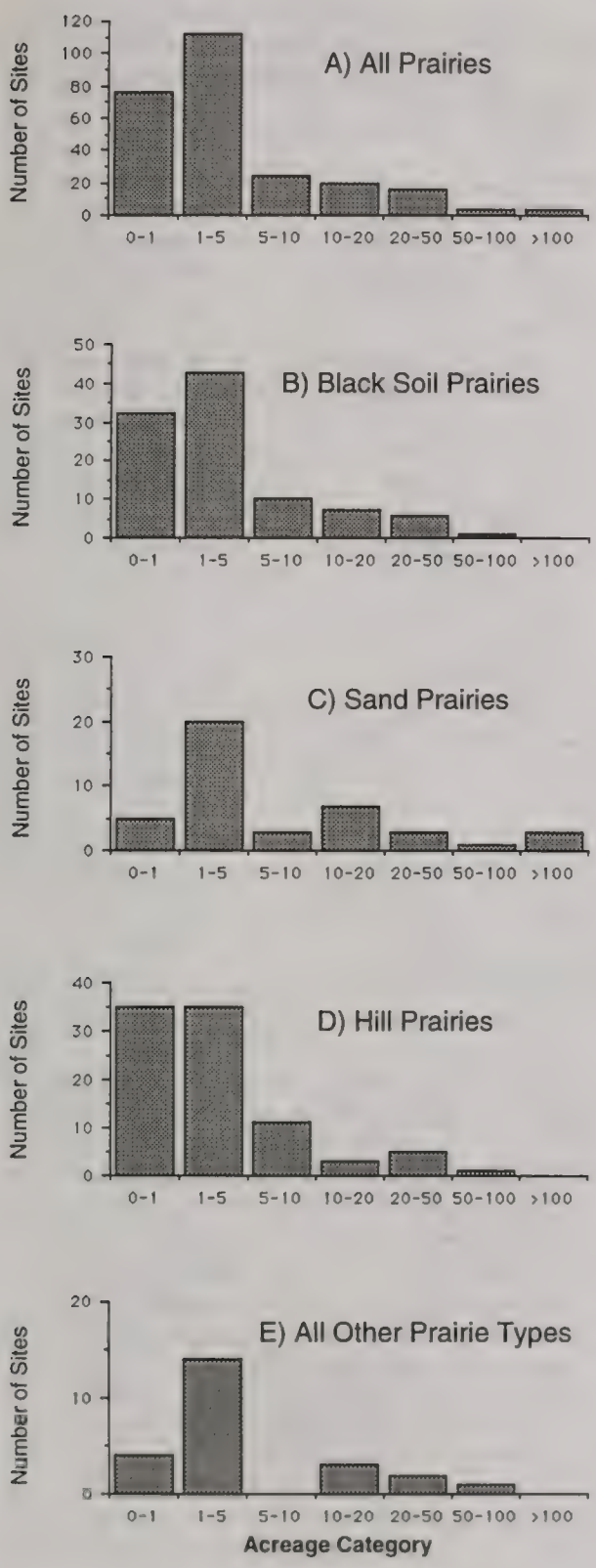

Figure 6. Number of grade A and B prairies by prairie type and size category (Source: Illinois Natural Areas Inventory).

the 253 prairie sites identified by the Illinois Natural Areas Inventory, 83% are smaller than 10 acres and 30% are less than one acre! All remnants of the tallgrass prairie, in Illinois and elsewhere, lack the full complement of natural processes that operate at large scales, such as landscape fires, grazing by large mammals, and natural migrations of species and changes of species composition with fluctuations in rainfall.

Types of Prairies in Illinois. The natural landscape of Illinois can be divided into 14 natural divisions, based on topography, glacial history, bedrock, soils, and distribution of plants and animals (Schwegman 1973) (Figure 7). Various kinds of prairies occurred in each of these natural divisions. The prairies of Illinois were by no means a homogeneous stand of grasses and forbs. The Natural Areas Inventory (White 1978) recognizes six main subclasses of prairie: black soil prairie, sand prairie, gravel prairie, dolomite prairie, hill prairie, and shrub prairie. Further divisions are made based on soil moisture classes, yielding 23 prairie types in Illinois (Table 1). These different prairie types are the result of variations in soil moisture, soil composition, geological substrate, glacial history, and topography.

Biodiversity of Prairies

The tallgrass prairie is "the most diverse repository of species in the Midwest [and] . . . habitat for some of the Midwest's rarest species" (Chapman et al. 1990). It is rather difficult to give a total number of species that occur in Illinois prairies. Because the tallgrass prairie ecosystem is recently evolved, there are few endemic species; few prairie species are restricted to the prairie habitat. Most prairie species also occur outside the prairie region in habitats other than prairies. Prior to European settlement, the landscape of the tallgrass prairie in Illinois was a complex matrix with specialized communities embedded in the prairie — fens, pannes, sedge meadows, marshes, ponds, kames, sand blowouts, savannas, and prairie groves. The borders between these communities and the prairie fluctuated on both short- and long-term bases depending on rainfall, drought, and fire frequency. This ever-changing matrix adds to the problem of placing some species into the "prairie species" category. For this discussion we include all species that occupy or utilize during some stage of their life cycle the types of habitats recognized as prairie by the Illinois Natural Areas Inventory (Table 1); excluded are species restricted to open grass, sedge, and forb-dominated communities classified as wetlands, such as sedge meadows and fens.

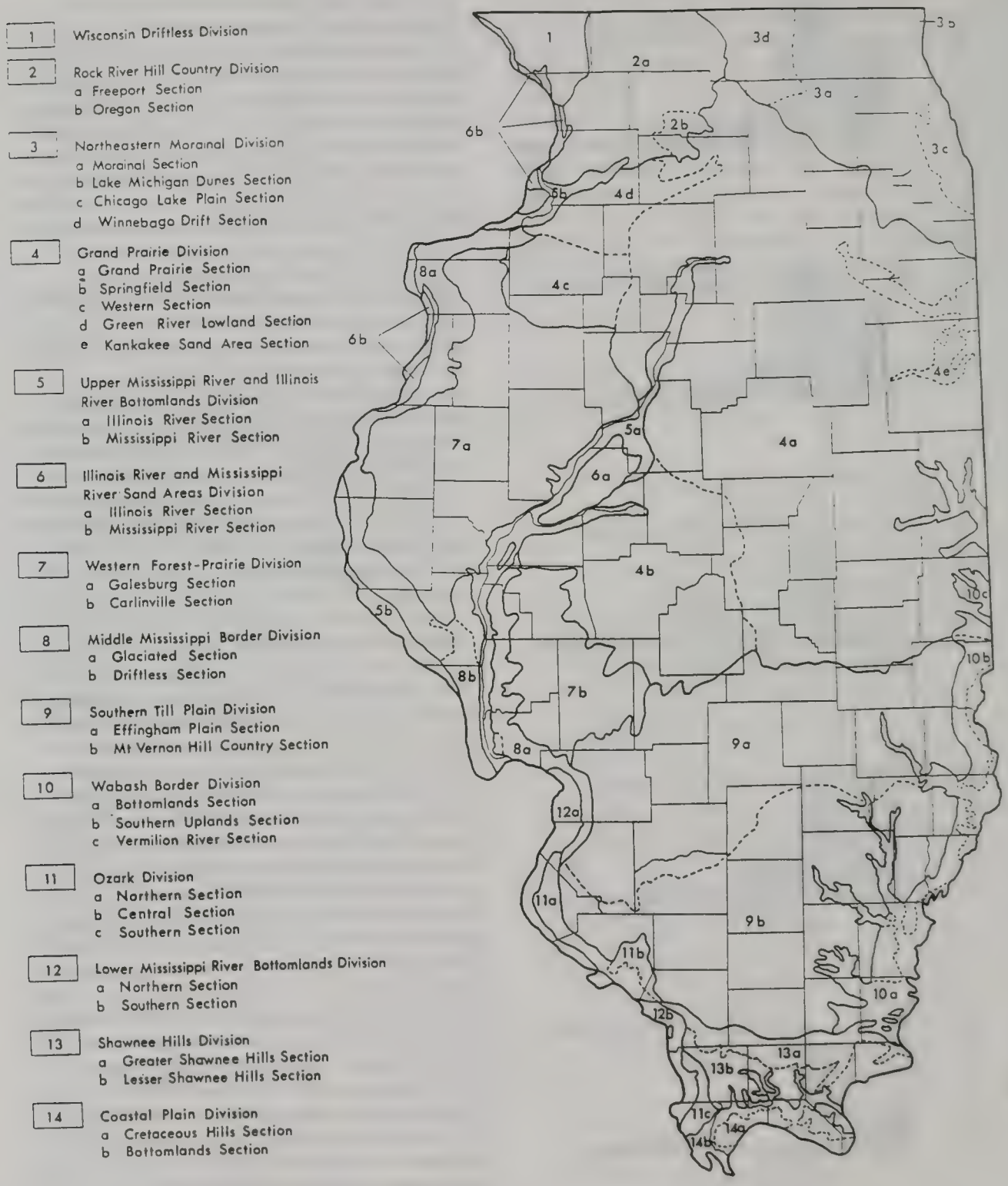
1 Wisconsin Driftless Division
2 Rock River Hill Country Division
a Freeport Section
b Oregon Section
3 Northeastern Morainal Division
a Morainal Section
b Lake Michigan Dunes Section
c Chicago Lake Plain Section
d Winnebago Drift Section
4 Grand Prairie Division
a Grand Prairie Section
b Springfield Section
c Western Section
d Green River Lowland Section
e Kankakee Sand Area Section
5 Upper Mississippi River and Illinois River Bottomlands Division
a Illinois River Section
b Mississippi River Section
6 Illinois River and Mississippi River Sand Areas Division
a Illinois River Section
b Mississippi River Section
7 Western Forest-Prairie Division
a Galesburg Section
b Carlinville Section
8 Middle Mississippi Border Division
a Glaciated Section
b Driftless Section
9 Southern Till Plain Division
a Effingham Plain Section
b Mt Vernon Hill Country Section
10 Wabash Border Division
a Bottomlands Section
b Southern Uplands Section
c Vermilion River Section
11 Ozark Division
a Northern Section
b Central Section
c Southern Section
12 Lower Mississippi River Bottomlands Division
a Northern Section
b Southern Section
13 Shawnee Hills Division
a Greater Shawnee Hills Section
b Lesser Shawnee Hills Section
14 Coastal Plain Division
a Cretaceous Hills Section
b Bottomlands Section

Figure 7. The natural divisions of Illinois (reprinted from Schwegman 1973).

Table 1. Number of acres of various prairie types in Illinois. Data for 1978 from White (1978); 1992 data from Illinois Natural Areas Inventory database.

	1978	1992
Blacksoil Prairie		
Dry prairie	30.4	30.4
Dry-mesic prairie	299.3	289.7
Mesic prairie	803.9	622.1
Wet-mesic prairie	1,054.3	1,050.3
Wet prairie	1,041.3	818.0
Sand Prairie		
Dry sand prairie	926.8	924.3
Dry-mesic sand prairie	672.5	671.0
Mesic sand prairie	397.3	389.2
Wet-mesic sand prairie	76.2	76.2
Wet sand prairie	300.7	300.7
Gravel Prairie		
Dry gravel prairie	83.2	71.3
Dry-mesic gravel prairie	50.6	48.9
Mesic gravel prairie	27.7	27.7
Dolomite Prairie		
Dry dolomite prairie	29.6	29.6
Dry-mesic dolomite prairie	9.0	9.0
Mesic dolomite prairie	37.0	37.0
Wet-mesic dolomite prairie	59.7	59.7
Wet dolomite prairie	5.0	5.0
Hill Prairie		
Loess hill prairie	463.0	459.1
Glacial drift hill prairie	51.5	51.5
Gravel hill prairie	14.7	14.7
Sand hill prairie	5.2	5.2
Shrub Prairie	180.0	180.0

Plants. Using various sources, Widrlechner (1989) compiled a list of 862 species of plants native to prairies of the midwestern United States. The Illinois Plant Information Network (ILPIN) is a computerized database listing life-history, habitat, taxonomic, and distributional information available on the vascular flora of Illinois (Iverson 1992). The ILPIN database records 851 species of plants native to Illinois prairies. Examining the diversity of Illinois prairies by county (Figure 8) shows that this diversity differs from region to region. The Chicago region, with its large diversity of prairie types, contains many prairie species. Many species also occur along the Mississippi and Illinois rivers. Somewhat surprising is the large number of prairie species in extreme southern Illinois that occur in the numerous small prairie openings there.

This level of plant diversity, however, is not likely to be found on any single prairie. A general pattern of increasing diversity with size of a habitat patch, referred to as the species/area curve, is commonly observed across a wide range of taxonomic groups and habitat types (Gleason 1922, MacArthur and Wilson 1967, Harris 1984). The species/area curve observed in the flora of prairies suggests that patches larger than 10 acres contain most of the local diversity of plants, approximately 100 species (Figure 9). Unfortunately, fewer than 17% of all remaining prairies in Illinois are above this size threshold (Figure 6). Nevertheless, a substantial amount of floristic diversity is preserved in small habitat patches since the mean patch size for grade A and B prairie remnants in Illinois is quite small. The apparent local maximum level of diversity (100 species), though, is far below what may be found in most counties in Illinois (Figure 8). Perhaps this is because most species are uncommon, as demonstrated by two floristic surveys of small prairie fragments in Illinois and Indiana (Betz and Lamp 1989, 1992). In both studies, most species were found in fewer than four sites (Figures 10, 11). Therefore, the complement of species found on any given prairie remnant is likely to be individualized and somewhat unique. Any further loss of prairie fragments represents the potential for a serious erosion of the floristic diversity of the state because of the relatively few good habitat patches in which many of these species are currently found.

Birds. As one might expect, the dramatic change in the landscape after European settlement resulted in equally dramatic changes in bird populations. Several Illinois bird population studies, beginning in the mid-1800s and continuing through 1989, have provided insight into these changes.

At first the change from prairie to agricultural land caused an increase in several bird species with the formation of pastures and hayfields—that is, secondary grasslands (Graber and Graber 1963). These secondary grassland habitats became acceptable breeding grounds for a majority of prairie birds (Graber and Graber 1963). The prairie-chicken especially benefited from this new combination of food and cover as well as the decrease in animal predators. It is thought that the dickcissel, another prairie bird whose numbers increased early on, actually preferred these secondary grasslands over the original prairie (Kendeigh 1941, Graber and Graber 1963, Zimmerman 1971). Despite increased populations of some prairie birds throughout Illinois, however, Graber and Graber (1963) found that population changes were negligible for most species between 1909 and 1956.

Some species considered very common or abundant before 1900 decreased slightly in numbers early in this

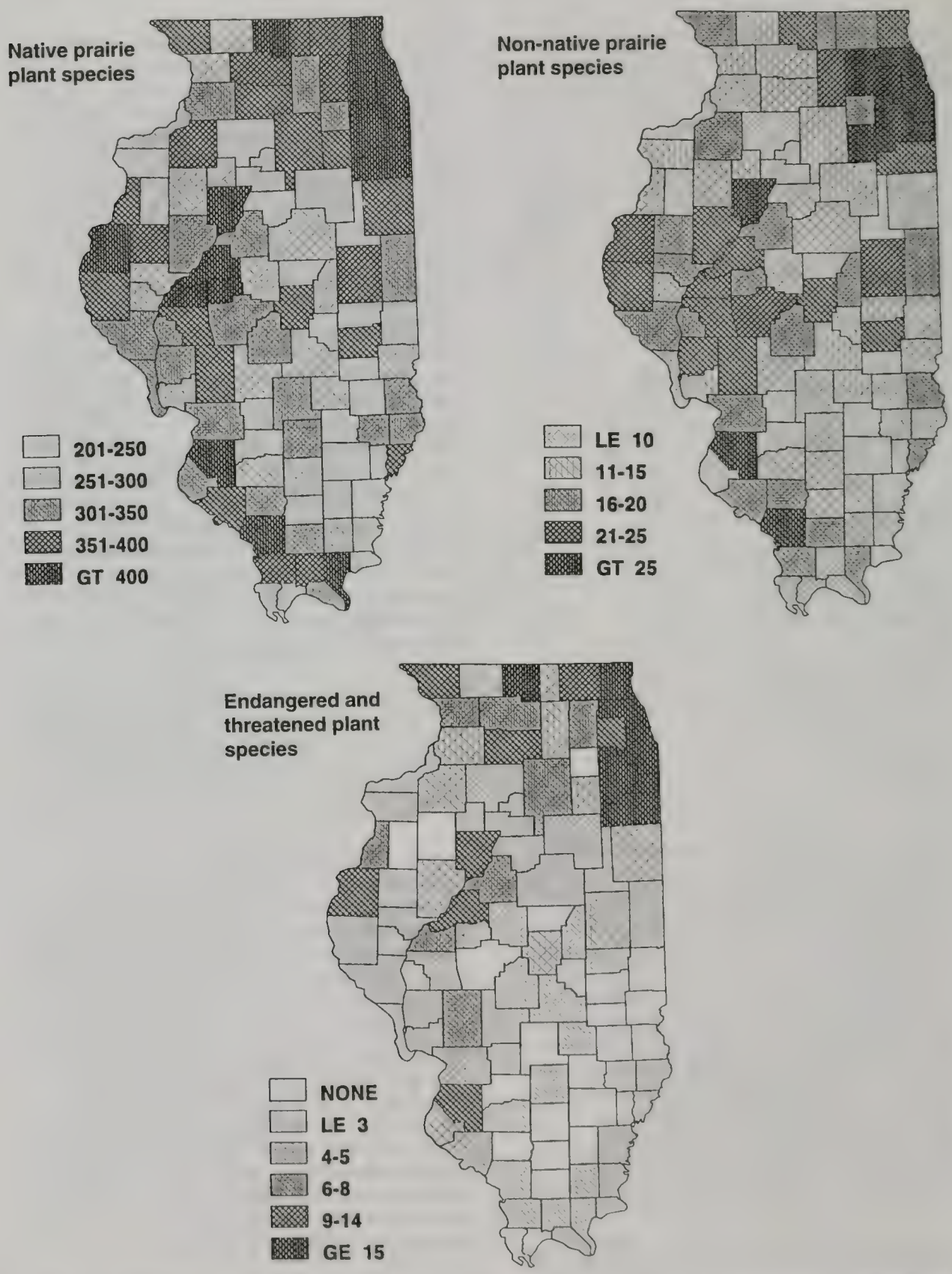

Figure 8. The number of prairie plant species (top left), non-native prairie plant species (top right), and endangered and threatened plant species (bottom) in each Illinois county (Source: Illinois Plant Information Network).

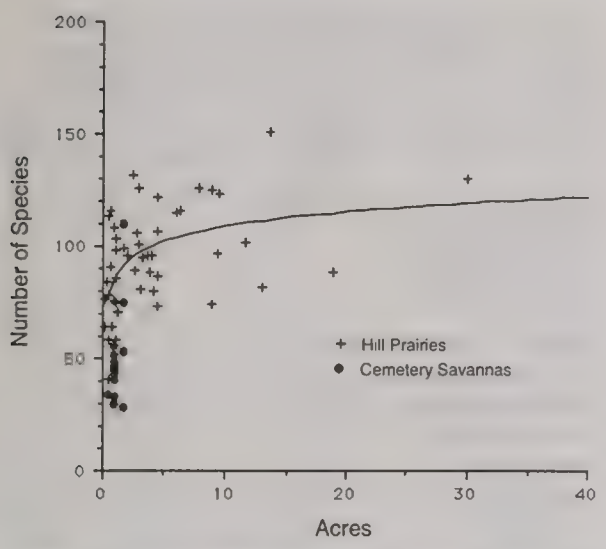

Figure 9. Number of species censused in prairie remnants of various sizes, demonstrating that diversity of prairies increases with size (Sources: Evers, unpublished data; Betz and Lamp 1992; Betz and Lamp 1989).

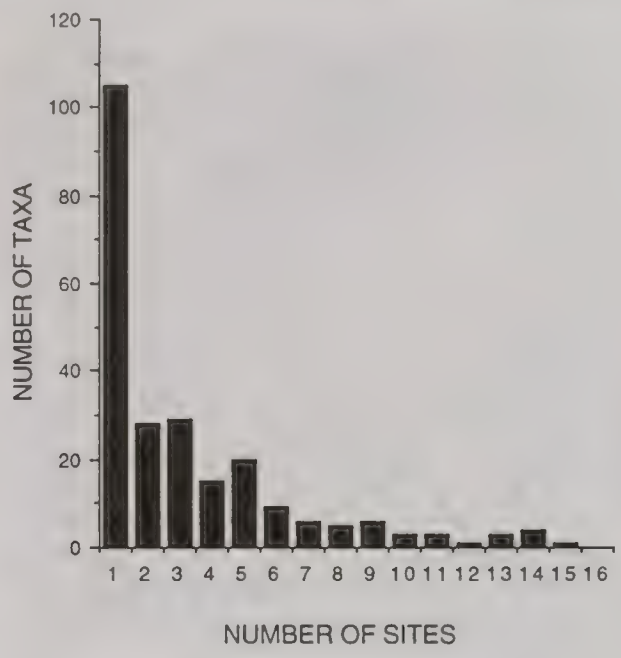

Figure 10. Number of sites in which each of 238 native taxa were found in a survey of 16 remnant prairie and savanna cemeteries in Illinois and Indiana (Source: Betz and Lamp 1992).

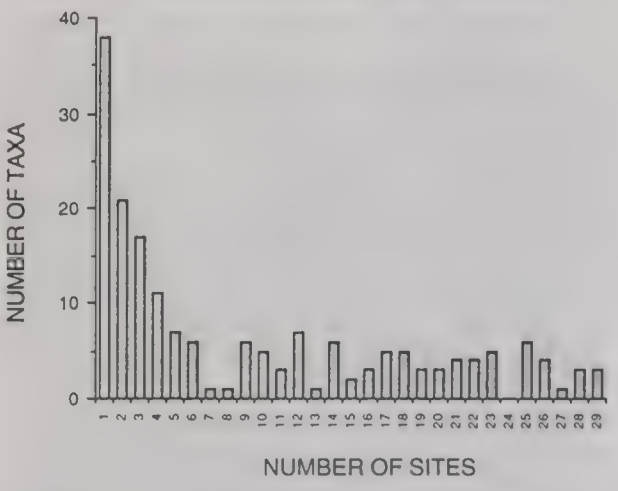

Figure 11. Number of sites in which each of 180 native taxa were found in a survey of 29 remnant black soil prairies in Illinois and Indiana (Source: Betz and Lamp 1989).

century, and others have been declining sharply (Figure 12). A decline in almost all prairie bird populations in Illinois occurred from 1967 to 1989 (United States Fish and Wildlife Services breeding bird survey, unpublished data) (Table 2).

Although the cause of this decline is not fully known, it is thought to be related to the ongoing depletion of Illinois grassland habitat. A decrease in hay production (Illinois Agricultural Statistics Service 1988, 1989) coupled with pasture reduction (U. S. Department of Commerce Bureau of the Census 1989) has resulted in a loss of secondary grasslands on top of the depletion of the original prairie. This overall loss of Illinois grassland habitats is partially responsible for the current fragmented landscape. As a result of habitat fragmentation, changes have occurred that may have important consequences for breeding birds. Most obviously, a reduction in habitat results in a reduction of individuals, local populations, or perhaps even species. Less obvious but also important to breeding birds is that smaller habitats may lack essential resources and provide less of a buffer in the event of natural catastrophes or predators. Although only three species of prairie birds have been eliminated from Illinois, 13 more species are considered threatened or endangered, mainly because of habitat loss.

One of the birds included on the endangered list has experienced an enormous decline in numbers due more to the invasion of its habitat by a non-native species than to a reduction of habitat. In 1860, the state of Illinois was home to 10 million greater prairie-chickens (Westemeier 1983, Westemeier 1990, Westemeier and Edwards 1987), a species that had survived in large numbers over several thousand years despite native predators such as coyotes, skunks, and opossums. Although much of the prairie was gone by 1912,

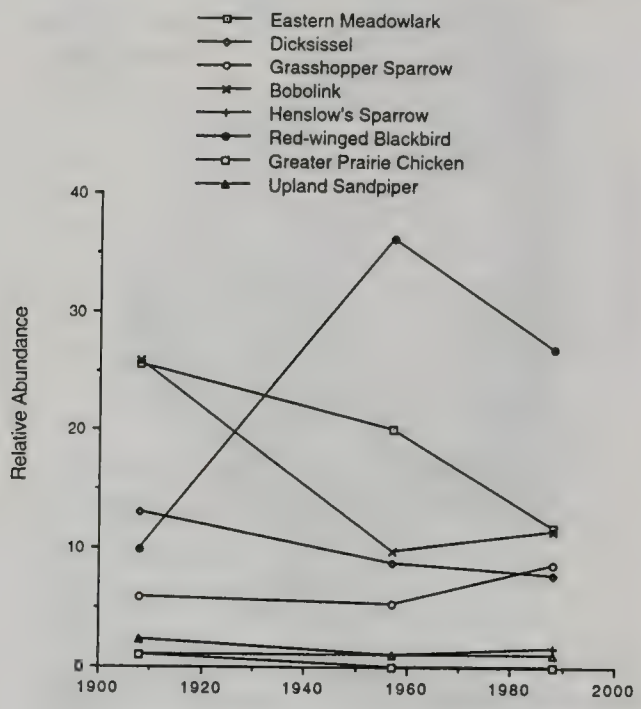

Figure 12. Twentieth century trends in populations of grassland birds cited to have been abundant or very common prior to 1900 (Source: Herkert 1989).

Table 2. Relative abundance of various prairie bird species in Illinois before 1900 and changes in species populations from 1967 to 1989. A = abundant; VC = very common; C = common.

Species	Prior to 1900[1]	USFWS % change 1967–1989[2]
Eastern meadowlark	A	–67.0
Dickcissel	A	–46.7
Grasshopper sparrow	A	–56.0
Bobolink	A	–90.4
Henslow's sparrow	A	*
Red-winged blackbird	VC	–18.8
Greater prairie chicken	VC	*
Upland sandpiper	VC	–16.8
Vesper sparrow	C	+12.1
Horned lark	C	0.0
Field sparrow	C	–52.6
Song sparrow	C	–29.3
Savannah sparrow	C	–58.9
American goldfinch	C	–42.8
Common yellowthroat	C	–8.8
Sedge wren	C	–22.5

[1] Based on the work of Nelson (1876) and Ridgway (1889, 1895).
[2] Estimated population change within Illinois between 1967 and 1989 based on the United States Fish and Wildlife Service's breeding bird survey (USFWS, unpublished data).
*Present on too few routes for accurate trend analysis.

prairie-chickens still occupied 92 counties but quickly decreased in numbers with the release and establishment of ring-necked pheasants (Figure 13). As of 1989, there were less than 100 prairie-chickens in Illinois (R. Westemeier, Illinois Natural History Survey, Champaign, personal communication). Sanctuaries were established in areas around the state to insure that suitable habitat for prairie-chickens would always exist. Unfortunately, these sanctuaries are also desirable for pheasants, which have become the greatest threat to prairie-chickens.

The greatest problem associated with the coexistence of prairie-chickens and pheasants appears to be the result of hen pheasants "parasitizing" or laying eggs in the nest of prairie-chickens. Pheasant eggs hatch about two days earlier than those of prairie-chickens, sometimes causing the hen to leave the nest before her own chicks have hatched. Even if both eggs are hatched, the problem of harassment of prairie-chicks by the larger pheasant chicks can occur. The survival of any species depends on successful reproduction, and the prairie-chicken has not been able to effectively coexist with the pheasant.

Insects. Vertebrates constitute but a small fraction of the animal species found in terrestrial ecosystems. Most animals are invertebrates, and most invertebrates are insects. An estimated 17,000 species of insects occur in Illinois (Post 1991); several thousand of these must have originally inhabited the vast Illinois prairie. Fortunately, most seem to have survived the near total destruction of their pre–European settlement habitats. A majority of these animals inhabit a variety of humanized habitats, such as pastures, hayfields, parks, yards, and fencerows. Some insect species have actually benefited from the alteration of their presettlement plant communities and can often be found in exaggerated numbers throughout Illinois (R. Panzer, Northeastern Illinois University, personal communication).

A smaller but significant number of prairie insect species have not managed to adapt to the modern Midwestern landscape (for examples, see Table 3). These "conservative" species are very discriminating in their choice of habitats and are rarely found outside of the context of their native plant communities. Isolated as small populations on small, widely scattered prairie remnants, these species must contend with excessive edge effects and the high extinction rates associated with island-dwelling organisms. Having lost more than 99.99% of their presettlement habitats, this group of remnant-requiring animals is clearly vulnerable to the ongoing alteration of the Illinois landscape.

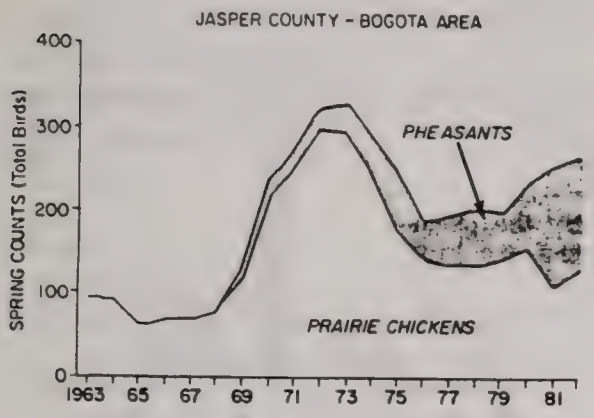

Figure 13. Spring counts of prairie-chickens and pheasants on the Bogota Study Area, Jasper County, Illinois, 1963–1982. Pheasants are represented by the shaded area above the prairie-chicken population (reprinted from Westemeier 1983).

Table 3. Insect species previously reported to occur in the prairie area within Illinois Beach State Park that are no longer found there (R. Panzer, personal communication).

Leafhoppers
Hecalus rotundus
Flexamia delongi
Polyamia compacta
Hebecephalus signatifrons
Hebecephalus cruciatus
Deltocephalus gramus
Euscelis sahlbergi
Limotettix parallelus
Paraphlepsius altus
Chlorotettix obsensus
Chlorotettix rugicollis
Chlorotettix brevidis
Butterflies
Hesperia ottoe
Callophrys irus
Moths
Schinia indiana

Insect surveys have been conducted within a variety of humanized habitats and on 56 Illinois prairie and savanna remnants since 1982 (R. Panzer, unpublished data). The primary focus of this study has been on leafhoppers, froghoppers, butterflies, root-borer moths (*Papaipema* species), and flower moths (*Schinia* species), groups that are generally reported to include inordinately high numbers of prairie-dependent species. Grasshoppers, grouse locusts, katydids, walking sticks, stinkbugs, shieldback bugs, treehoppers, and bumblebees, insects that are widely reported to be tolerant of habitat alteration, were also considered. The primary objectives of this study were to generate estimates of conservatism for each group and to determine the status, distribution, and site size requirements of the conservative species in northern Illinois.

Six hundred forty species belonging to the groups surveyed have been recorded within northern Illinois in the past 100 years. Eighty-five percent of these insects have been relocated since 1982 (Figure 14). At least three-quarters have been recorded in one or more humanized habitats and can currently be considered to be secure (Figure 15). Roughly 25% of the species considered here have been found to be restricted to prairie and savanna remnants. Roughly two-thirds of these conservative species are seemingly secure, surviving on at least a dozen protected sites. Approximately one-fifth are known from fewer than six sites and are clearly imperiled. Prominent examples include moths such as the *Eryngium* root-borer (*Papaipema eryngii*) and the loosestrife root-borer (*Papaipema lysimachia*), both of which are known to survive only on one or two protected sites. A small number of species, such as the Indiana flower moth (*Schinia indiana*), the Harris checkerspot (*Chlosyne harrisii*), and the Dakota skipper (*Hesperia dacotae*), have not been relocated and likely have been extirpated from Illinois.

Most of the prairie and savanna remnants in Illinois are very small and widely spaced, precluding the exchange of species and individuals between sites. The data presented here suggest that most Illinois remnants continue to support prairie-dependent species. Sites of 100 acres have been found to support as many prairie-dependent species as do sites that are 10 times larger, suggesting that losses on sites within this size range have been slight (Figure 16). Species diversity decreases dramatically at sites smaller than 100 acres. Only 3 of the 253 (1.2%) grade A and B prairies in Illinois are larger than 100 acres.

Truly small remnants appear to have lost species (Figure 16). That there have, in fact, been losses in species diversity on even the largest sites is similarly clear. Two butterfly, one moth, and a dozen leafhopper species, all of which were recorded within the large prairie that has since been protected as Illinois Beach State Park, have not been seen in many years and are presumed to have been extirpated from this site (Table 3).

Finally, parallel studies within the large (1,000 acre) Fermilab Prairie Restoration indicate that prairie-

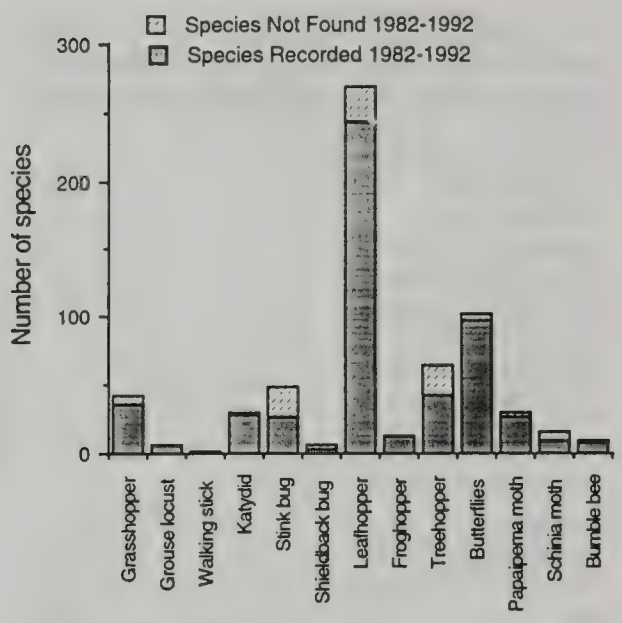

Figure 14. Among prairie insect species described in the early 20th century in northern Illinois, number of species in various taxonomic groups that were either found or not found in northern Illinois between 1982 and 1992 (Source: R. Panzer, unpublished data).

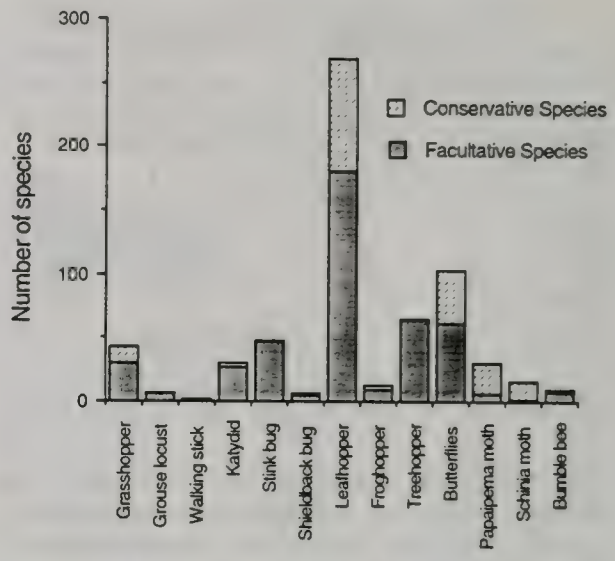

Figure 15. Among insect species of various groups found in prairies in northern Illinois, proportion occurring almost exclusively in prairies (conservative species) and proportion often found in other habitats as well (facultative species) (Source: R. Panzer, unpublished data).

dependent insect species cannot be expected to return unaided to prairie plantings. Despite its "huge" size, this prairie recreation contributes little to the conservation of prairie butterflies in Illinois (Figure 16).

In summary, available data suggest that, although a majority of the prairie insects have adapted to the modern Illinois landscape, scores of species have not. The conservation of the remnant-dependent animals can clearly be best served by preserving the prairie remnants upon which they depend (Panzer 1988). It has been found that hill prairies in Iowa, which contain the largest remaining tracts of prairie in that state, serve as significant refugia for butterflies and other invertebrates (Orwig 1992). Hill prairies in Illinois need to be studied to see if the same happens in our state.

Endangered Species. Because 99.99% of the natural prairies in Illinois have been destroyed, the numbers of individuals of all prairie plants and animals are very small today compared with 1820, although no precise figures are available. Many species have become so rare that they are listed as endangered or threatened. Currently, 497 species are listed as endangered or threatened in Illinois (Illinois Endangered Species Protection Board 1990); 401 are endangered and 96 are threatened (J. Herkert, personal communication). Of

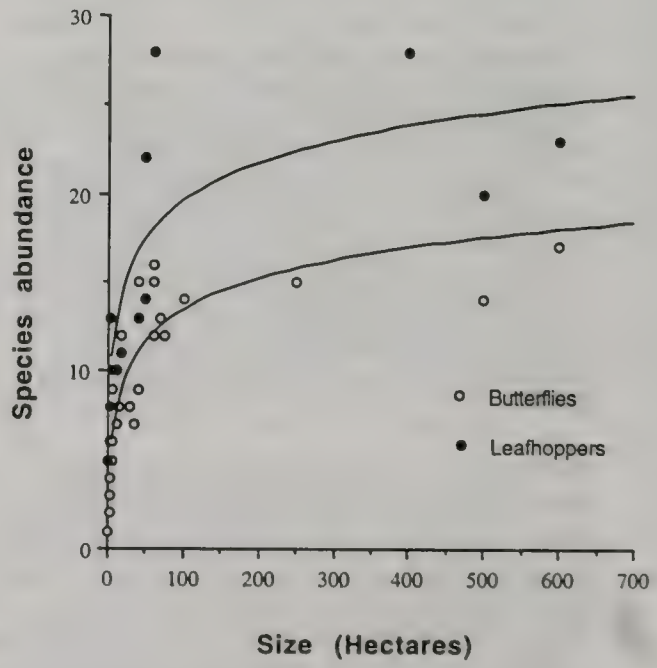

Figure 16. Relationship between species diversity and prairie area for leafhoppers and butterflies. Diversity generally increases with increasing prairie size (Source: R. Panzer, unpublished data).

Table 4. Total number of endangered (E) and threatened (T) species in Illinois and number of these that are prairie species.

	Total E	Total T	Prairie E	Prairie T
Fishes	15	15	0	0
Reptiles & amphibians	7	5	2	2
Birds	37	6	10	3
Mammals	7	3	1	0
Invertebrates	41	7	1	2
Plants	296	60	77	18

these species, 116 (23%) occur on prairies. These species are summarized by group in Table 4, and the individual species are listed in Table 5.

The distribution of the endangered and threatened (E & T) plant species is not uniform throughout the state (Figure 8). By far the largest concentration is in the Chicago region, largely as a result of high ecological diversity; the western part of the state also has a number of E & T prairie species, mostly in hill and sand prairies. About half of the plant species listed in Table 4 are essentially restricted to sand prairies, dunes, or beaches.

Particularly striking is the dearth of E & T species in central Illinois, due to the nearly total loss of habit; also, few E & T plant species occur in blacksoil prairies. As an example, the prairie white-fringed orchid (*Platanthera leucophaea*) was once widespread on the blacksoil prairies and has been reported historically from 33 counties. Today it is known only from mostly small populations in eight counties, and some of these are under threat by non-native species, unscrupulous collection, and lack of proper management practices (Herkert 1991a, b). Of the 45 species of the orchid family of plants (Orchidaceae) native to Illinois, 19 (42%) are listed as endangered or threatened. Other E & T plant species were likely always uncommon in Illinois, being at the edge of their natural ranges. Some examples include Mead's milkweed (*Asclepias meadii*), large-flowered beard-tongue (*Penstemon grandiflorus*), and primrose violet (*Viola primulifolia*). Silvery bladderpod (*Lesquerella ludoviciana*) and leafy prairie clover (*Petalostemum foliosum*) are widely disjunct from other populations of the species.

Four taxa of plants are endemic to Illinois: Kankakee mallow (*Iliamna remota*), Sangamon phlox (*Phlox pilosa* subsp. *sangamonensis*), decurrent false aster (*Boltonia decurrens*), and American thismia (*Thismia americana*). The last is likely extinct (see below), and the second is restricted to prairies and forest openings along the Sangamon River in Piatt and Champaign counties. The Kankakee mallow, while not considered a prairie species, grows in gravel soils on an island in the Kankakee River, and some prairie species occur on the island. Decurrent false aster (*Boltonia decurrens*) was probably endemic to alluvial prairies and marshes along the Illinois and Mississippi rivers in Illinois. Today, this species no longer occurs in prairies per se.

Several animals that occurred on the prairies have been extirpated from Illinois within historic time, such as the bison, elk, prairie wolf, mountain lion, and black bear (Hoffmeister 1989). Four birds that occurred on the prairies in Illinois were listed as extirpated by Bowles et al. (1980): whooping crane, sharp-tailed grouse, American swallow-tailed kite, and sandhill crane. The sandhill crane has since reappeared in the state, and the whooping crane and American swallow-tailed kite are very rare migrants (Bohlen and Zimmerman 1989). Extirpated prairie insects are the Dakota skipper, Indiana flower moth, and Harris checkerspot see Post 1991).

As far as we know, only one plant species that occurred in Illinois prairies is both extirpated from Illinois and extinct. This plant, *Thismia americana*, was last seen in 1914 (Mohlenbrock 1983). Other prairie plant species that have been extirpated from Illinois but that occur in other states are Drummond rock cress (*Arabis drummondii*), wild blue larkspur (*Delphinium carolinianum* var. *penardii*), blanket flower (*Gaillardia aestivalis*), and running buffalo clover (*Trifolium stoloniferum*) (Post 1991). The lake-side daisy (*Hymenoxys acaulis* var. *glabra*) formerly was found in dolomite and gravel hill prairies, but the last naturally occurring population in Illinois was destroyed in 1981. However, plants from an Illinois population are in cultivation; unfortunately, this species must be cross-pollinated, and the cultivated plants represent the same breeding type. These cultivated plants have been crossed with plants from Ohio and Ontario to produce fertile offspring, which have been used in an attempt to reintroduce the species into natural areas in Illinois.

Non-native Plant Species. A recent estimate (Post 1991) indicates that there are 2,068 species of vascular plants in Illinois. The most recent floristic manual (Mohlenbrock 1986) gives the total number of vascular plants known to be native or naturalized as 2,853. Using these figures, about 27.5% of the vascular plants growing spontaneously in Illinois were introduced from other regions, especially Europe, eastern Asia, and other parts of North America. Slightly different figures have been obtained using other sources of data

Table 5. Endangered (E) and threatened (T) species of Illinois prairies. Intial data supplied by J. Herkert; plant list modified by Natural History Survey staff.

Plants		
Agropyron subsecundum	bearded wheat grass	E
Artesemia dracunculus	false taragon	E
Asceplias lanuginosa	woolly milkweed	E
Asclepias meadii	Mead's milkweed	E*
Asclepias ovalifolia	oval milkweed	E
Asclepias stenophylla	narrow-leaved green milkweed	T
Astragalus crassicarpus var. *trichocalyx*	large ground plum	E
Astragalus tennesseensis	Tennessee milk vetch	E
Beckmannia syzigachne	American slough grass	E
Besseya bullii	Kittentails	T
Betula populifolia	gray birch	E
Boltonia decurrens	decurrent false aster	T*
Botrychium simplex	dwarf grape fern	E
Bumelia lanuginosa	wooly buckthorn	E
Calopogon tuberosus	grass pink orchid	T
Camassia angusta	wild hyacinth	E
Carex atherodes	sedge	T
Carex aurea	golden sedge	E
Carex austrina	sedge	E
Carex crawei	sedge	T
Carex tonsa	sedge	E
Castilleja sessiliflora	downy yellow painted cup	E
Ceanothus ovatus	redroot	E
Comptonia peregrina	sweetfern	E
Corydalis curvisiliqua var. *grandibracteata*	corydalis	T
Cyperus grayioides	umbrella sedge	T
Cypripedium calceolus var. *parviflorum*	small yellow lady's slipper	E
Cypripedium candidum	white lady's slipper	E
Cypripedium reginae	showy lady's slipper	E
Drosera intermedia	narrow-leaved sundew	T
Eriophorum viridi-carinatum	tall cotton grass	E
Erythronium mesochoreum	white dog-tooth violet	E
Filipendula rubra	queen-of-the-prairie	T
Fimbristylis vahlii	Vahl's fimbristylis	E
Heliotropium tenellum	slender heliotrope	E
Hexalectris spicata	crested coralroot orchid	E
Hudsonia tomentosa	false heather	E
Hymenoxys acaulis var. *glabra*	lakeside daisy	E*
Hypericum kalmianum	Kalm's St. John's wort	E
Juncus alpinus	Richardson's rush	E
Juncus vaseyi	Vasey's rush	E
Lactuca ludoviciana	western wild lettuce	E
Lechea intermedia	pinweed	E
Lespedeza leptostachya	prairie bush clover	E*
Lesquerella ludoviciana	silvery bladderpod	E
Lycopodium clatatum	running pine	
Lycopodium dendroideum	ground pine	E
Lycopodium inundatum	bog clubmoss	E
Microseris cuspidata	prairie dandelion	E
Mirabilis hirsuta	hairy umbrella wort	E
Oenothera perennis	small sundrops 1	E
Opuntia fragilis	fragile prickly pear	E
Orobanche fasciculata	clustered broomrape	E
Orobanche ludoviciana	broomrape	E
Panicum boreale	northern panic grass	E
Paspalum bushii	hairy bead grass	E
Penstemon grandiflorus	large-flowered beard tongue	E
Petalostemon foliosum	leafy prairie clover	E
Phacelia gilioides	phacelia	E
Phlox pilosa subsp. *sangamonensis*	Sangamon phlox	E
Platanthera ciliaris	orange fringed orchid	E
Platanthera clavellata	wood orchid	E
Platanthera flava var. *herbiola*	tubercled orchid	T
Platanthera leucophaea	prairie white fringed orchid	E*
Platanthera psycodes	purple fringed orchid	E
Pogonia ophioglossoides	snake-mouth	E
Polanisia jamesii	James' clammyweed	E
Polygala incarnata	pink milkwort	E
Polygonum careyi	Carey's heartsease	E
Populus balsamifera	balsam poplar	E
Potentilla millegrana	cinquefoil	E
Ranunculus rhomboideus	prairie buttercup	T
Rubus setosus	bristly blackberry	E
Rudbeckia missouriensis	Missouri orange coneflower	E
Rumex hastatulus	sour dock	E
Sabatia campestris	prairie rose gentian	E
Salvia azurea subsp. *pitcheri*	blue sage	T
Sanguisorba canadensis	American burnet	E
Silene regia	royal catchfly	E
Silphium trifoliatum	rosinweed	E
Sisyrinchium atlanticum	eastern blue-eyed grass	E
Sisyrinchium montanum	mountain blue-eyed grass	E
Sphaeralcea angusta	globe mallow	E
Spiranthes lucida	yellow-lipped lady's tresses	E
Spiranthes vernalis	spring lady's tresses	E
Stylisma pickeringii	Patterson bindweed	T
Talinum calycinum	fameflower	E
Thismia americana	thismia	E
Tomanthera auriculata	ear-leafed foxglove	T
Tradescantia bracteata	prairie spiderwort	E
Triadenum virginicum	marsh St. John's wort	E
Trifolium reflexum	buffalo clover	E
Trillium viride	green trillium	T
Viola primulifolia	primrose violet	E
Viola viarum	plains violet	E
Zigadenus glaucus	white camass	E
Amphibians		
Pseudacris streckeri subsp. *illinoensis*	Illinois chorus frog	T
Birds		
Ictinia mississippiensis	Mississippi kite	E
Circus cyaneus	northern harrier	E
Tympanuchus cupido	greater prairie-chicken	E
Coturnicops noveboracensis	yellow rail	E
Laterallus jamalcensis	black rail	E
Grus canadensis	sandhill crane	E
Bartramia longicauda	upland sandpiper	E
Tyto alba	common barn owl	E
Asio flammeus	short-eared owl	E
Lanlus ludovicianus	loggerhead shrike	T
Spizella pallida	clay-colored sparrow	E
Ammodramus henslowii	Henslow's sparrow	T
Euphagus cyanocephalus	brewer's blackbird	T
Mammals		
Lepus townsendii	white-tailed jackrabbit	E
Reptiles		
Clemmys guttata	spotted turtle	E
Kinosternon flavescens	Illinois mud turtle	E
Heterodon nasicus	western hognose snake	T
Invertebrates		
Hesperia ottoe	ottoe skipper	T
Hesperia metea	cobweb skipper	T
Atrytone arogos	arogos skipper	E

* Federally threatened

(Henry and Scott 1980, Reed 1988; see also the section on non-native species in the chapter on wetlands). In any case, the number of non-native species has increased dramatically with European settlement, from 10.2% in 1846 to something around 30%. Using species distribution information from the ILPIN database, one finds that non-native species are most prevalent in the Chicago region, western Illinois, and southwestern Illinois (Figure 8). Recently, the reality that non-native species can be disruptive of natural ecological communities has been reflected in the enactment of the Illinois Exotic Weed Act (Gould and Gould 1991).

Non-native species can be divided into three categories. The first are extremely serious weeds that outcompete native species and threaten to destroy natural plant communities in the prairies. The second category of non-native species that occur regularly in prairies are adapted to current climate and management practices, are not overly aggressive, and are not likely to further significantly change species composition or frequency in prairies. The third category includes species that will probably be eliminated with proper management practices. These are species that either persist from cultivation or are opportunistic in disturbances in the prairies.

Different prairies have different disturbance and management practices that affect the occurrence of non-native species. For example, black-soil cemetery prairies are different from other prairie remnants in that they often contain species that were planted as ornamentals.

In a study of 44 pioneer settler cemeteries on silt-loam soil, Betz and Lamp (1989) found a total of 180 native species, 73 non-native herbaceous species, 22 species of both native and non-native woody plants, and 13 species of cultivated forbs. In a subsequent study of 16 old settler savanna and sand prairie cemeteries, Betz and Lamp (1992) found 238 native prairie or savanna species, 22 species of woody plants, 54 species of weedy native or non-native herbaceous plants, and 14 species of cultivated forbs (Figure 17). A combined species list for three central Illinois blacksoil prairie pioneer cemetery nature preserves—Loda Cemetery, Prospect Cemetery in Paxton, and Weston Cemetery (K. Robertson, Illinois Natural History Survey, unpublished data), each about 5 acres—shows a total of 186 species, of which 46, or 24.7%, are non-native.

The two most serious non-native species at Loda Cemetery are daylily (*Hemerocallis fulva*) and teasel

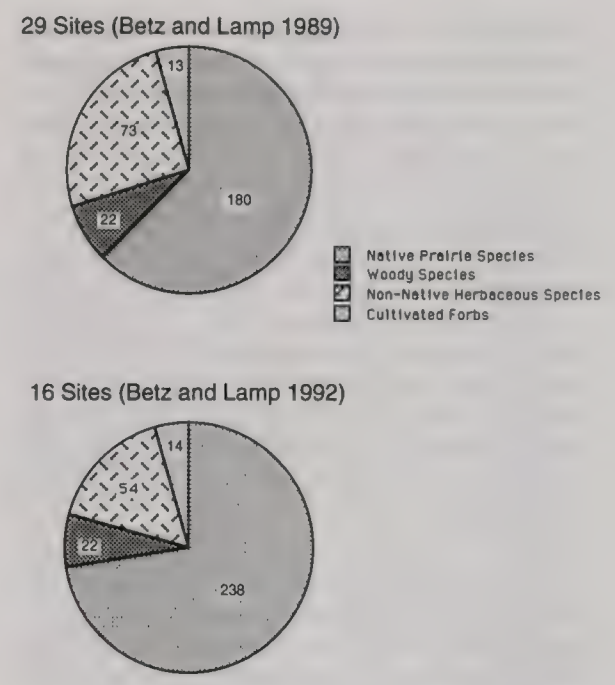

Figure 17. Proportion of taxa that are native and herbaceous, woody, non-native herbs (weeds), and cultivated forbs (weeds) on 29 black soil prairie remnants (top) and 16 sand and gravel prairie remnants (bottom) in Illinois and Indiana (Source: Betz and Lamp 1989, 1992).

(*Dipsacus laciniatus*). Since 1978, these species have increased greatly, and one large colony of daylily has nearly divided the prairie in half, crowding out all native vegetation. Teasel is a good example of the necessity to understand the biology of a species before undertaking control measures. Because teasel is a biennial species, initial attempts at control involved hand-cutting the flowering stalks and leaving them in the prairie to add to biomass for burning the following spring. Unfortunately, enough stored energy remains in the cut stalks for seed to set (Solecki 1989, Glass 1991). Control measures now include transporting the cut stalks off site as well as very early spring burns (late January in 1993) when the winter rosettes are exposed and native plants are dormant. At Prospect Cemetery, the most detrimental non-native species are daylily, periwinkle (*Vinca minor*), white popular (*Populus alba*) (Glass 1992), cypress spurge (*Euphorbia cyparissias*), and white and yellow sweet clovers (*Melilotus alba, M. officinalis*) (see Cole 1991). Fortunately, Weston Cemetery is mostly free from non-native plant species in this category.

Although teasel was introduced from Eurasia prior to this century (Werner 1975), it has only recently spread in Illinois to become a problem weed (Glass 1991, Solecki 1989). The expansion of both common and cut-leaved teasel appears to have been assisted by two phenomena. First, the location of population centers along interstate highway rights-of-way suggest that cut-leaved teasel moves with highway construction. Horticultural use of common teasel in floral displays at gravesites has resulted in numerous colonizations of cemetery prairies (Swink and Wilhem 1979). Cut-leaved teasel, a recent invader, was first recorded in Missouri in 1980 near Kansas City. Vast populations can now be found along Illinois roadsides where there were few or no populations only 5–10 years ago (Glass 1991, Solecki 1989).

In moister prairies, especially in the Chicago region, common buckthorn (*Rhamnus catharica*), glossy buckthorn (*R. frangula*), and various bush honeysuckles (*Lonicera maackii, L. morrowii, L. tatarica*) can be serious problems (Heidorn 1991). Black locust (*Robinia pseudoacacia*) is a problem in the sand prairies of central Illinois. Another troublesome species in some sand prairies is sour dock (*Rumex acetosella*). Most plant species that invade and encroach upon hill prairies are native woody species, although black locust is invasive on some hill prairies.

The second category of non-native species includes widespread but benign species that occur with regularity in prairies. They appear to be adapted to current climate and management practices, are not overly aggressive, and are not likely to dramatically change species composition in the prairies. There are numerous examples of these in blacksoil prairies, including Queen-Anne's-lace (*Daucus carota*), wild parsnip (*Pastinaca sativa*) (Kennay and Fell 1992), asparagus (*Asparagus officinalis*), ox-eye daisy (*Chrysanthemum leucanthemum*), and moneywort (*Lysimachia nummularia*). Blackberry-lily (*Belamcanda chinensis*) is in this category on hill prairies. Kentucky blue grass (*Poa pratensis*) and Canada blue grass (*P. compressa*) occur widely in many types of prairies. They are cool-season grasses and begin to grow before most of the native species break dormancy. Although these are a serious problem in some prairies, they do not generally seem to be as extremely disruptive as species in the first category, and they appear impossible to eliminate from prairies; mid-spring burns may, however, help reduce the frequency of occurrence.

The third category includes species that will probably be eliminated with proper management practices. These are species that either persist from cultivation or are opportunistic in disturbances in the prairies. Examples include flowering almond (*Prunus glandulosa*), lily-of-the-valley (*Convallaria majallis*), cultivated iris (*Iris* species), chicory (*Cichorium intybus*), and Adam's needle (*Yucca filamentosa*).

EXAMPLE OF HILL PRAIRIES

Hill prairies are situated atop bluffs of the Mississippi River Basin from around St. Paul, Minnesota, to the southern tip of Illinois; extensive hill prairies also occur along the Missouri River in western Iowa (Novacek 1985, Novacek et al. 1985). Within Illinois, they occur along the Mississippi River, the Illinois River from its junction with the Mississippi River to Putnam County, and along the Sangamon River in Menard and Mason counties (Evers 1955, Kilburn and Warren 1963) (Figure 18). Most of the hill prairies in Illinois are loess hill prairies (Table 1). Glacial drift hill prairies occur in Coles and Vermilion counties of east-central Illinois (Reeves et al. 1978, Ebinger 1981). Before European settlement, it is likely that hill prairies never formed large continuous segments in Illinois but were fragmented by ravines that dissect the river bluffs and slopes and delimited on the upland sides by forest.

Hill prairies typically occupy southwest-facing portions of steep slopes where some combination of hot summer sun, dry prevailing winds, and periodic fire preclude forest vegetation (Evers 1955, Ranft and Kilburn 1969, Bland and Kilburn 1966, Reeves et al. 1978). The flora of these insularized xeric habitats is a combination of typical prairie species, species disjunct from the western plains region, and hill prairie endemics. The most common species are little bluestem (*Schizachyrium scoparium*), side oats grama (*Bouteloua curtipendula*), and daisy fleabane (*Erigeron strigosus*) (Anderson 1972, Kilburn and Ford 1963). In the survey of nine hill prairies discussed below, researchers found little bluestem and side oats grama to be by far the most frequent in occurrence (Table 6), and 22 species were found in more than 10% of the meter-square plots. Because of their relative inaccessibility, typical agricultural activities such as tillage have not been prevalent in these habitats. During field work for the Illinois Natural Areas Inventory of 1976-1977, 446 hill prairies were examined, many less than 1 acre; only 127 were relatively undisturbed by grazing by domestic livestock (Nyboer 1981). Nevertheless, hill prairies remain as some of the last living windows into the ecology of the prairie biome that dominated Illinois for 8,000 years prior to European settlement.

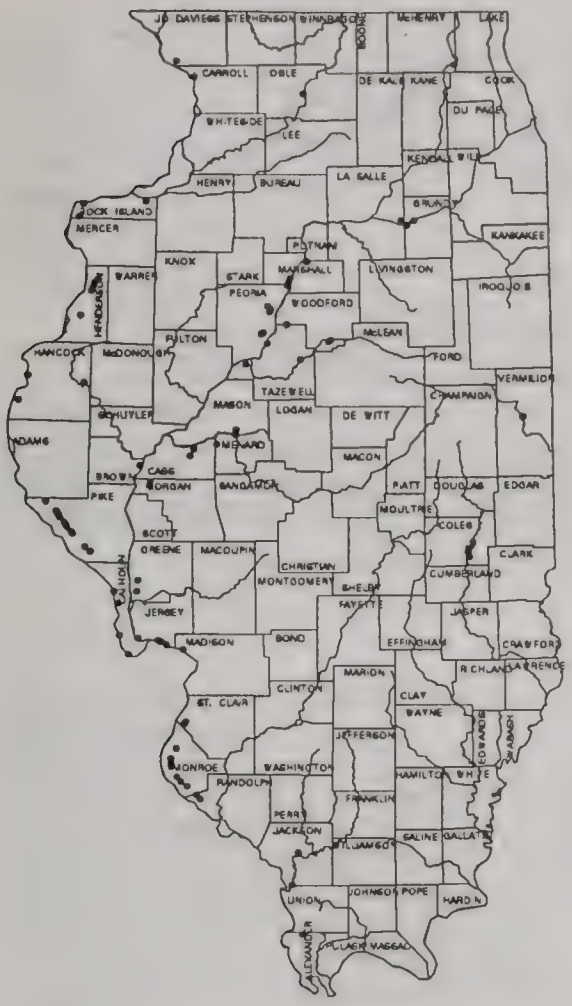

Figure 18. Locations of natural areas with hill prairie components in Illinois (Source: Illinois Natural Areas Inventory).

The Illinois Natural Areas Inventory has identified 90 sites containing about 400 acres of grade A and B hill prairies (Figures 6, 19). Reports suggest, however, that these remaining sites are being lost at an alarming rate (White 1978, Werner in press). In a study of hill prairies in Pere Marquette State Park in Jersey County, McClain (1983) compared aerial photographs of the area taken in 1937 and 1974. It was found that the hill prairies were reduced in size by 61.9% in the 37-year interval. This decrease was due to the invasion of the hill prairies by woody plants.

To address the issue of the loss of hill prairie, Natural History Survey staff investigated the rate of loss in area of extant hill prairies during the past 50 years. To do this, researchers used aerial photos from 1940 to the

Table 6. Most common plant species in nine Illinois hill prairies. Column A = percentage of meter-square plots in which the species was found; Column B = average percentage of each plot that was covered by the species.

Species	A	B
Schizachyrium scoparium	64.6	30.49
Bouteloua curtipendula	62.4	13.50
Andropogon gerardii	27.5	25.90
Dicanthelium spp.	29.8	2.68
Aster azureus	29.2	5.29
Psoralea tenuiflora	27.5	12.24
Petalostemum purpureum	37.1	3.41
Ruellia humilis	12.9	0.96
Cornus drummondii	15.2	14.38
Juniperus virginiana	11.2	20.60
Solidago nemoralis	22.5	3.14
Senecio plattensis	16.3	0.37
Melilotus alba	18.0	9.05
Rhus glabra	15.7	27.60
Ambrosia artemisiifolia	14.6	12.55
Eupatorium altissimum	13.5	2.74
Aster ericoides	16.3	9.81
Euphorbia corollata	15.2	1.47
Kuhnia eupatorioides	10.7	2.57
Asclepias verticillata	10.7	2.12
Aster patens	12.9	2.47
Cassia fasciculata	14.0	4.48

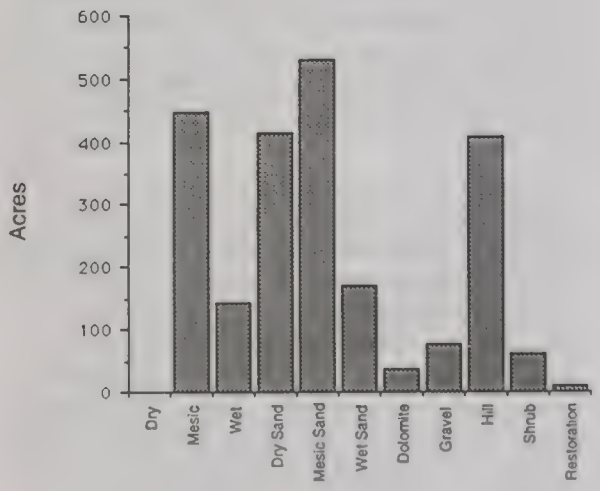

Figure 19. Number of acres of grade A and B prairies of various types in Illinois in 1992 (Source: Illinois Natural Areas Inventory).

present. They digitized the aerial extent of nine hill prairies in Illinois. The results suggest that hill prairies have, on average, been halved in acreage since 1940 (Figure 20). This estimate does not include sites that are no longer hill prairies and is thus a conservative estimate of the total rate of habitat loss.

Eight of the nine study sites are quite small, covering from 1 to about 7 acres; only Revis is fairly large. The data show that Revis has decreased in size from 39.16 acres in 1939 to 17.37 in 1988 (Figure 20). In addition to losing significant area, hill prairies are becoming more fragmented as previously continuous areas are divided by woody invasion, especially in small ravines traversing the hill prairies.

Much of this loss of hill prairie is from woody invasion around the borders of sites, especially by red cedar, smooth sumac, and rough-leaved and flowering dogwoods. The perimeter-to-area ratio (P/A) is used to estimate the susceptibility of habitat patches to colonization from adjacent habitats. During the 50-year interval encompassed in the recent Natural History Survey study, the average P/A ratio increased by over 100% (Figure 21). Thus, not only are our hill prairies declining from woody invasion at an alarming rate, but the propensity for this woody invasion is accelerating. This phenomenon is illustrated by the observation that sites with a high P/A ratio tend to loose larger proportions of their areas during the study period (Figure 22). It is thought that, under present climate conditions, hill prairies will suceed to forest in the absence of fire (Kilburn and Warren 1963, McClain 1983, Schwegman and McClain 1985). A concomitant study of the biological diversity of sites shows that sites that maintain more of their original area during the study period tend to be more diverse in terms of plant species (Figure 23).

The results of this study point to a single clear trend—namely, the loss of this rare habitat within Illinois. The Illinois Department of Conservation is currently taking measures to protect some hill prairie sites through active fire management (J. Schwegman and W. McClain, personal communication). There is much debate on the natural fire frequency for hill prairies; estimates range from 1 to 30 years. When combating advanced recruitment of woody invaders, managed fire frequencies may need to exceed natural levels until woody invasion is suppressed. Even under a fire management program, woody invaders may need to be removed through cutting to restore hill prairie habitats.

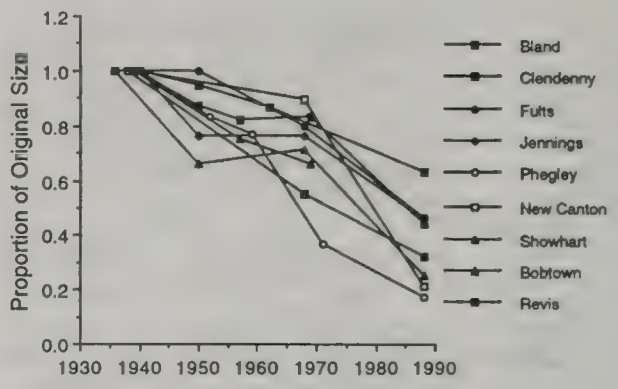

Figure 20. Change in size of nine Illinois hill prairies between 1940 and 1988 as assessed through aerial photography. Each site decreased in size only through the process of woody species invasion from adjacent habitats.

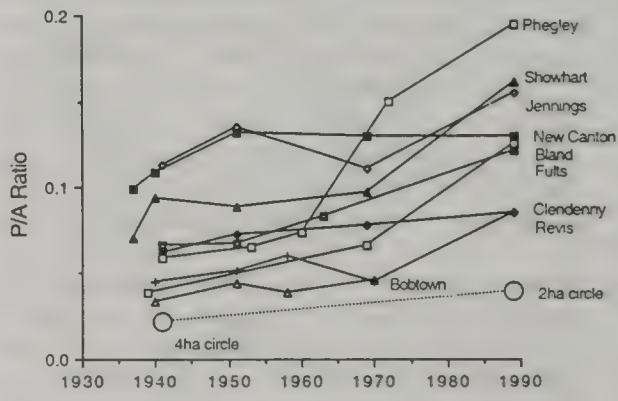

Figure 21. Changes over time in the perimeter-to-area (P/A) ratios for nine Illinois hill prairies. For comparison, the P/A ratios for two circles (4 and 2 ha), representing the average beginning and ending sizes of the hill prairies sampled, are presented.

CONCERNS ABOUT GENETIC DIVERSITY IN PRAIRIE PLANTS

We will never know for certain how the drastic habitat loss and fragmentation affected the genetics of prairie species during the initial period of habitat loss (1820–1900), but the question remains, What genetic factors are important for managing the tallgrass prairie remnants of today? To properly manage the prairie systems of Illinois we must understand how genetic variation is distributed and what plant life history traits influence this distribution. Population differentiation tends to occur when the exchange of genetic material (gene flow) between populations is limited. Gene flow

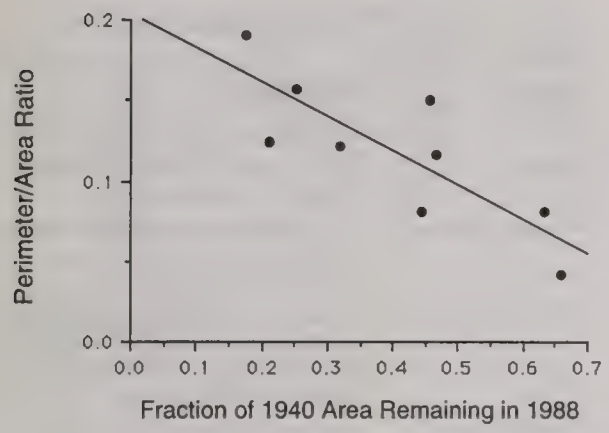

Figure 22. The 1988 perimeter-to-area ratio plotted against the fraction of the 1940 area remaining in 1988 for nine Illinois hill prairies, indicating a tendency for sites with more edge to lose a greater proportion of area.

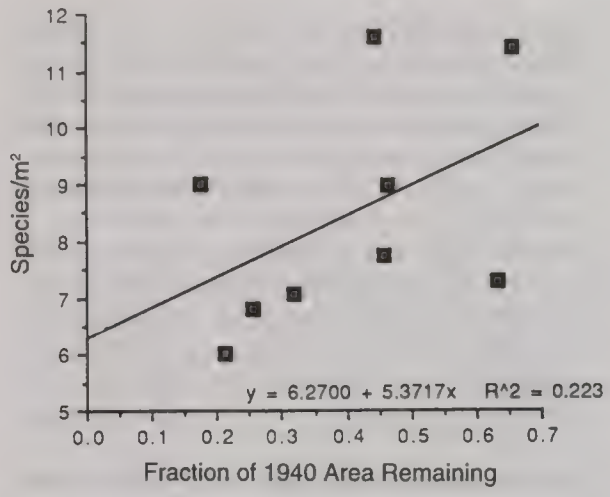

Figure 23. Relationship between the rate of loss of hill prairie area between 1940 and 1988 and species richness per square meter. Sites that have lost the largest proportion of their original area tend to have lower diversity.

is mainly influenced by plant mating systems and dispersal mechanisms.

Several efforts have been made to summarize likely levels of genetic variability and population differentiation (Loveless and Hamrick 1984, Hamrick and Godt 1990, Hamrick et al. 1991). Observational evidence shows that obligate outcrossers have high levels of genetic variability, and that much of this genetic variability is distributed across populations such that individual populations are not genetically distinct or differentiated from one another. We can, in fact, visualize a continuum with self-fertilizing species with narrowly dispersed seed at one end and with outcrossing, wind-pollinated species with widely dispersed seed at the other. At the first end, we expect to see much opportunity for population differentiation, and at the other, little opportunity.

In any closed population, random genetic change tends to result in loss of genetic diversity over time. These effects are more pronounced in small populations than in large ones. It has long been noted that small population size can lead to inbreeding depression, or a reduced ability of the species to reproduce (Barrett and Kohn 1991). All organisms carry a complement of recessive alleles that are deleterious. Small population size (e.g., < 50 individuals) increases the chances of creating individuals with a pair of homozygous recessive alleles, allowing the deleterious character to be expressed in the individual. Severe inbreeding depression can render a population unsustainable, or inviable, in a given environment (Menges 1991). Not all species, however, will exhibit inbreeding depression with small population sizes (Huenneke 1991, Templeton 1991). Species with low genetic variability also tend to carry few deleterious recessive alleles.

In species with high levels of genetic diversity (wind pollinated outcrosser with widely dispersed seed) deleterious genes will usually not be eliminated. When populations size dramatically drops, genetic diversity also declines and deleterious genes are more frequently expressed. It is likely that some of these traits will impair the function of the individual, causing inbreeding depression.

Some work has been done concerning genetic variation of tallgrass prairie plants (reviewed in Dennis and Harry 1988). In general, warm-season grasses (*Andropogon gerardii, Schizachyrium scoparium, Panicum virgatum,* etc.) are wind-pollinated, outcrossing, and long-lived perennials. These characteristics suggest a lower potential vulnerability to loss of genetic diversity. However, these are the sort of species that are predicted to suffer deleterious impacts when population size is suddenly reduced. Information for cool-season grasses is sparse. Western wheatgrass (*Agropyron smithii*) is similar to the warm-season grasses, while Canada wild-rye (*Elymus canadensis*) is a selfer and would be less vulnerable to the deleterious effects of rapid population decline.

Most prairie forbs that have been studied are insect-pollinated outcrossers (Parrish and Bazzaz 1979). Given this, one would expect moderate levels of differentiation between populations (not much pollen or seed dispersal over great distances) and moderate levels of within-population variation (little tendency to lose variability, as with selfing). One would expect these species to carry a considerable load of deleterious genes that become a problem when population levels decrease rapidly. While most prairie forbs are perennial, prairie annuals are of particular concern because they undergo genetic recombination on a yearly basis and would more rapidly express inbreeding depression.

Although species in all natural habitats within Illinois may be susceptible to inbreeding depression due to small population size, researchers are particularly concerned about prairie plants. Prairie preserves are often very small, sometimes less than an acre; the population size for many species on these sites may be no more than a few individuals. As a result, inbreeding depression can develop relatively quickly. Although many species are likely candidates for inbreeding depression, there are few examples of actual inbreeding depression in prairie preserves. This lack of evidence, however, may simply reflect the fact that very few studies have specifically addressed the reproductive biology of prairie species.

STRESSES TO PRAIRIE ECOSYSTEMS

This chapter briefly reviews the extensive changes that have occurred on Illinois grassland ecosystems. Some of the most dramatic of these changes, such as habitat loss, are beyond our ability to correct. Because of these extensive changes, an appropriate question is, What aspects of natural grassland ecosystems should we, or can we, conserve? Table 7 summarizes most major factors that have changed as a result of human influence in Illinois grasslands.

These extensive anthropogenic changes have eliminated the ability of all but the largest of our remaining grasslands (Nachusa Grasslands, Goose Lake Prairie, and Illinois Beach State Park being exceptions) to exist as fully functioning ecosystems. Two centuries of change in these grassland habitats, without consideration of the many factors that are working in unison to generate these changes, have left our grasslands quite different from what they probably were prior to European settlement. The challenge is how to manage what remains to maintain as much biological integrity as possible.

Table 7. Major anthropogenic changes in Illinois grassland ecosystems.

Factor	Ramifications
Destruction of habitat	> 99.99% loss of natural grassland habitats.
Drainage	With drainage of agricultural lands, native grasslands systems have dried out.
Nitrogenous pollutants	Fertilization increases ability of non-native species to invade and increases the probability of local species loss.
Fragmentation	Increases probability of local extinctions as a result of small population phenomena. Increases probability of further habitat degradation and species loss.
Climate change	May result in loss of local diversity, or shifts in relative abundance of species.
Fire suppression	Increases invasion of woody species. Shifts in relative abundance of species.
Non-native species	Sometimes can displace native flora and fauna.
Extirpation of bison	These large herbivores have been lost on Illinois grasslands and cannot be replaced under current habitat abundances and patch sizes.
Domestic livestock	Facilitate invasion by non-native grasses. Loss of biodiversity.

Conservation organizations have taken three different approaches to managing lands to maintain biological diversity (Figure 24). The traditional approach has been to manage lands for particular species of interest to humans (Figure 24, Path A). Prior to the 1970s this typically meant managing for game species such as deer, pheasant, and waterfowl. This emphasis has shifted to include endangered and threatened species. Conservation organizations propose that we should be managing to maximize the diversity of naturally occurring flora and fauna (Figure 24, Path B). This argument has been used to debate the issue of the appropriate frequency of managed fire in grasslands. In particular, fire management with respect to plant diversity versus insect diversity may differ (Stannard 1984). The third approach is to mimic historical abiotic conditions (such as fire) and restore these functions of the environment (Figure 24, Path C).

These management philosophies suggest that the different strategies vary in their abilities to drive systems back toward their pristine state (Figure 24). The facts are, however, that we cannot actually measure what the pristine environment should be, much less how to get there. Thus, we are left with a management decision on which pathway to follow. One might argue that this is contextual and depends on which types of ecosystems one is trying to conserve.

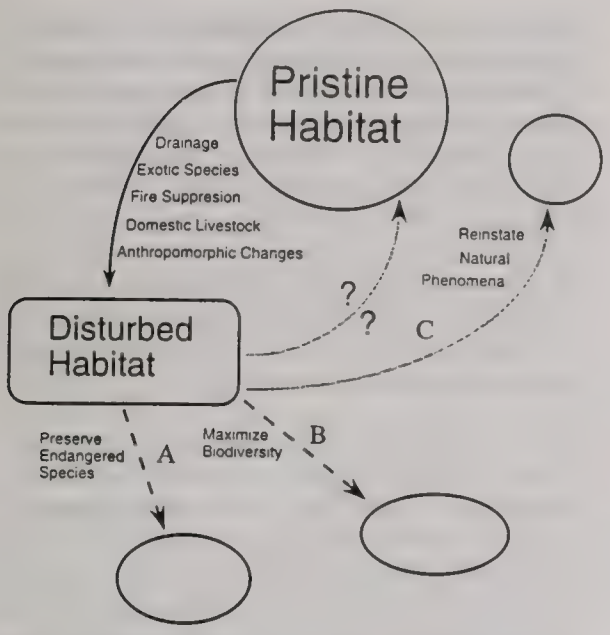

Figure 24. Strategies for natural lands management. The goal of management is typically to restore the land to a pristine, presettlement state. This goal can be achieved by (A) preserving species on a case-by-case basis, (B) using any and all management tools to maximize native biological diversity, and (C) restoring natural processes to mimic presettlement conditions. All three pathways are often assumed to lead to the same goal, and to work in unison with one another, but they may quite often violate this assumption.

Within large habitat patches we can actually try to maintain ecosystem functions. Thus, we can effectively pursue a management strategy that reintroduces many of the naturally occurring disturbances to grassland systems (such as bison and fire), while other ecosystem-level functions such as drainage have not been as severely disrupted (Figure 24, Path C).

For the majority of smaller preserves managers have typically adopted a strategy to use whatever management tools achieve an appropriate community composition (Figure 24, Path B). Interest in maintaining global biodiversity, as well as state and federal legislation, requires us to apply a species-level management strategy (Figure 24, Path A) at sites where rare and endangered species currently reside. One hopes that paths A, B and C are not mutually exclusive, and that pursuing them suggests similar management actions, all leading toward a pristine environment. In many cases this may be true. In the interest of applying appropriate management strategies, however, we must recognize that these varying objectives may, in fact, result in different activities. A clear recognition of this will help clarify the goals outlined in the subsequent material on stressors to the grassland environment.

Destruction of Habitat

The single most important stress affecting the remaining prairies of Illinois is human exploitation. Consequently, the primary management strategy for the preservation/restoration of the remaining prairie remnants is a no loss policy combined with a vigorous restoration program.

Currently only 6% of the areas listed on the Illinois Natural Areas Inventory are afforded the maximum protection against future changes in land use as dedicated Illinois Nature Preserves. Seventy-eight percent of Illinois prairie areas are classified as unprotected.

The threats of destruction to these unprotected areas are numerous and include building and highway construction, railroad maintenance, grazing, and cemetery mowing. Seventy-three percent of these prairie areas are likely to experience major threats within five years, and 9% are in immediate danger (White 1978).

Drainage

Most of the land that was originally in mesic to wet blacksoil prairie has been drained as part of the conversion of the land for agriculture. As a consequence, the moisture regimes have changed for the small isolated prairie remnants because they are now surrounded by fields. Little can be done in this situation because the adjacent property owners do not want to discontinue drainage.

Nitrogen Pollution

Most prairie ecosystems are nitrogen limited (Wedin and Tilman 1992). Dominant tallgrass prairie grasses are very efficient consumers of nitrogen from the soil and deplete this resource. In general, sites that are seasonally nutrient limited support a higher diversity of plants than those supplied with ample nutrients. The reason is that fertilization alters the competitive balance between species and allows a few species to dominate at the expense of many others (Tilman 1987, Tilman and Wedlin 1991).

The floristic diversity of native prairie at least in part depends upon this nitrogen depletion by the dominant

warm-season grasses. In experimental tests, Wedin and Tilman (1992) found that native prairie grasses successfully outcompete and exclude introduced pasture grasses under low nitrogen conditions, whereas these weedy pests persist with nitrogen fertilization. Thus, seasonal depletion of soil nitrogen, it appears, is an integral part of the functioning of a healthy prairie ecosystem. Nitrogen pollution has dramatically increased during the middle portion of the 20th century as a result of agrichemical fertilization. Runoff and groundflow of these fertilizers may have localized effects on plant community composition in native prairie. Aerial deposition of nitrogen has also increased in Illinois. This presents the problem that nitrogen fertilization of prairie soils may be occurring even in fairly large and pristine grassland habitats and threatens their ability to conserve biological diversity.

Fragmentation

The potential impacts of fragmentation have been discussed previously in the sections titled "Example of Hill Prairies" and "Concern about Genetic Diversity in Prairie Plants."

Climate Change

Very few studies addressing the biological ramifications of global climate change have specifically addressed the potential changes in grassland ecosystems. The general predictions of climate change for Illinois include a 2–5°C increase in mean annual temperature, most of which will take the form of warmer winters. In addition, decreased growing season precipitation, resulting in lower soil moisture levels, is also predicted. Under natural conditions, these changes would be predicted to result in an expansion of grasslands (Holeridge 1964, Emanuel et al. 1985). Under current land-use conditions, it seems unlikely that there will be a dramatic shift in prairie versus forested regions within Illinois given that the difference seems to be largely controlled by fire regimes and underlying soils. Perhaps the best prediction that can be made at this time is that prairie habitats on poor soils may experience a decreased propensity for woody species invasion if, in fact, the climate becomes warmer and drier.

A potentially dramatic influence of climate change on prairie systems may come from the direct effect of increased atmospheric levels of CO_2 on prairie plants. Increased levels of CO_2, the primary atmospheric gas responsible for driving climatic change, affects the ways in which plants respond to their environment. A growing body of evidence suggests that an increase in CO_2 levels increases drought tolerance in many species (Farquhar and Sharkey 1982). This increased drought tolerance is important in prairie systems given that the differential response of species to water stress plays a large role in plant community dynamics. One way in which this has been illustrated is how increases in CO_2 differentially affect warm- and cool-season grasses (Bazzaz and Carlson 1984, Mooney et al. 1991, Melillo et al. 1990). Experiments are under way to determine whether these factors will shift the competitive balance between these species (e.g., Owensby et al. 1993).

Finally, climatic parameters often predict the distributions of species (Holeridge 1964, Davis 1988). This information has been used to suggest that changes in climate will alter the natural ranges of species (Davis 1988, Davis and Zabinski 1992). This is viewed as a problem in cases in which the current range does not overlap with predictions of the location of a range under modified climate (Figure 25). The net result could be a loss in biodiversity if migration of these species does not keep pace with climate change. With respect to Illinois prairie plants, however, this extinc-

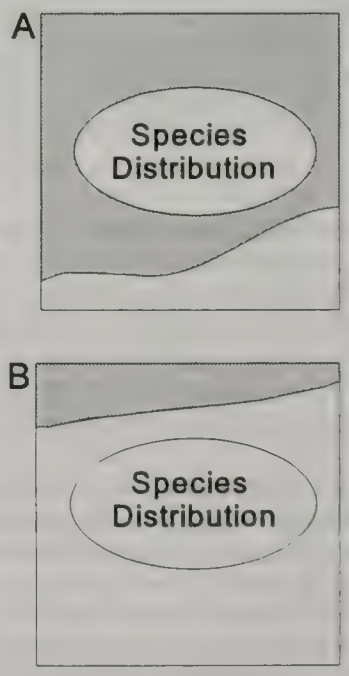

Figure 25. Hypothetical species distribution before climate change (A) and after climate change (B) in relation to climatic range (shaded area) of the species. Climatic warming may cause a species to disappear by displacing its range wholly outside the distribution of its climatic tolerance.

tion phenomenon is not likely to pose a serious threat. Situated along the eastern edge of the prairie, and with predictions of dry prairie-supporting conditions becoming more prevalent in Illinois, we are likely to experience an increased number of species that would be able to persist in Illinois prairies. The highly fragmented nature of prairies and low habitat availability make it unlikely that these species will actually be able to migrate into Illinois. The major area in which climate change may affect local diversity of prairie plants would be in the net loss of wet habitat area as conditions become more dry. With respect to animal diversity on prairies, there is no clear prediction that can be made with respect to climate change.

Fire Suppression

The tallgrass prairie of Illinois is considered a fire-adapted community (Henderson 1982). Historical records indicate that the prairies of Illinois burned frequently (McClain 1992). Considering this fact, it is not surprising that prescribed fire is the most important tool in the development, maintenance, and management of prairies.

Fire can be employed for two purposes in prairie management. In new restorations or neglected remnants, fire is used to directly suppress or kill non-prairie species. When fire serves this function, it is important to time the burn such that it coincides with the most vulnerable period in the target species life history (Illinois Nature Preserves Commission 1990). In a healthy system, fire is used to reduce accumulated litter and warm the soil, allowing the prairie plants to gain a competitive edge on their non-native competitors (Schramm 1990). Fires that serve this purpose are usually started in the early spring (although there is a trend toward more fall burning; see below).

When used properly, fire is very effective at controlling non-prairie species and is the preferred method. However, in cases in which fire is ineffective (purple loosestrife, autumn olive, wild parsnip, black locust, roadside prairies), managers need to employ methods that selectively remove undesirable vegetation.

In our smaller preserves we are most often managing grasslands to prevent further habitat loss through non-native and woody species invasion. The major tool used to accomplish these goals is fire. The predominant management goal has been to maintain diversity (Figure 24, Path B) by imposing fire regimes close to what probably occurred naturally (Figure 24, Path C). A better management strategy would be to recognize maintenance of biodiversity as the goal and determine what fire management strategy this suggests. Scientists have recently renewed the debate regarding the role of fire in maintaining grasslands. Although it is generally recognized that fire is essential for limiting the amount of woody growth on grassland habitats, some researchers have argued that fire can severely limit the diversity of insect fauna on small preserves. The argument for this goes as follows. If prairies were once extensive and generally wet in Illinois, the natural fire regime probably resulted in a patchy distribution of areas that remained unburned in any given fire event. These unburned patches, then, allow recolonization of burned areas by many insect species purported to be sensitive to fire.

Current prairie patches, however, may be too small to allow persistence of populations of sensitive species (Stannard 1984). Several pieces of information suggest that the impact of fire on potentially sensitive insect species is not as great as many suggest. First, there is the fact that most species described in northern Illinois during the early part of this century (during a period of fire suppression) have recently been found (Figure 14); if some subset of these species were very sensitive to fire, we would have lost more species. Second, recent information on an experiment measuring survival and recovery of a wingless prairie leafhopper (proposed as potentially very sensitive to fire) suggests that populations of this species begin to approach pre-burn densities during the first growing season following fire (Panzer, Stillwaugh, and Schwartz, unpublished data; Figure 26). These results suggest that even insect species whose life-history characteristics suggest a sensitivity to fire are able to survive current fire management regimes. Much additional work is needed in this area.

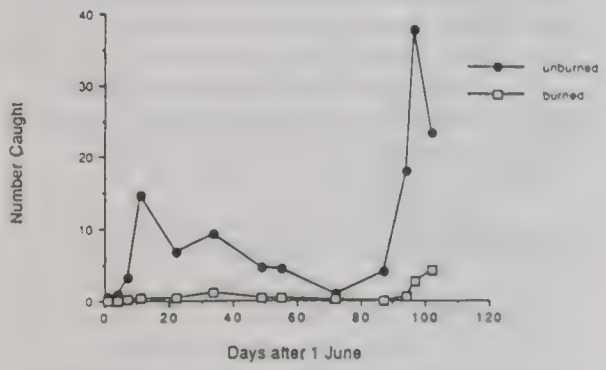

Figure 26. Densities of Aflexia rubranura *in sweep samples of burned and unburned areas of Goose Lake Prairie during summer 1992.*

Non-native Species

Impacts of non-native plant and animal species have been discussed previously. Most non-native species are here to stay, and little presently can be done to significantly reduce their frequency of occurrence in prairies. There are certain species that drastically alter the natural community structure, however, and management efforts should be directed toward these species. Diligent efforts are needed to contain and/or eradicate any newly introduced non-native species that have the potential to become serious problems. Controlling exotics through biocontrol agents may provide a cost-effective method for preserving the integrity of native habitats. Unfortunately, research directed toward development of biocontrol agents is restricted toward exotic species with a direct economic impact.

Extirpation of Bison

Large herbivores, such as bison, were formerly a strong ecological force affecting grassland habitats; more than 50 million bison roamed the prairies before settlement by Europeans. The vast majority of our now restricted habitat islands are, however, far too small to support even a single bison. Replacing this large grazer with others such as cattle is not an appropriate solution since their diets can be quite different. Likewise, the recent surge in deer populations (see chapter on forest) is affecting community dynamics in grassland systems where they were not before, causing concern among land managers.

Domestic Livestock

The grazing habits of domestic livestock are quite different from those of bison. Extensive grazing by non-native herbivores changes species frequency occurrence of native plant species and seems to also allow for the introduction and establishment of weedy plant species. Although there have been trials in other states to use cattle on native prairies to simulate grazing by bison, this technique is, at best, suited to prairie areas to the west of Illinois.

PRAIRIE MANAGEMENT

Current Practices

The primary management goals for prairie remnants are to increase species productivity and diversity and to reduce the encroachment of aggressive woody and non-native vegetation. In general, these goals are accomplished by three management practices: (1) prescribed burning, (2) selective removal of woody or non-native ground cover species, and (3) introduction of native ground layer species (discussed in the prairie restoration section to follow).

Mechanical control techniques such as mowing, girdling, cutting, and hand-pulling are a viable alternative to fire. Hand-pulling is recommended for purple loosestrife, autumn olive, Canada thistle, teasel, and wild parsnip (Illinois Natural Preserves Commission 1990).

The spot application of herbicides has been found to control several woody species on prairie sites (Illinois Nature Preserves Commission 1990). Herbicides used in conjunction with fire or mechanical measures are very effective in controlling undesirable plant species. For example, fall fire facilitates the control of *Melilotus alba* by inducing rapid early sprout growth, thereby allowing the application of a herbicide prior to the emergence of the other forbs (Schwegman and McClain 1985, Cole 1991).

It is important to remember that, regardless of the short-term control methods used to regulate non-native plant populations, the long-term goal of prairie management should be toward the restoration of the natural processes (fire, hydrology, etc.) that originally maintained the health of the system. Without this goal in mind managers are treating the symptoms and not the disease.

Suggested Changes in Management Practice

The two most needed changes in Illinois prairie management strategies are in the frequency and timing of fire. In Illinois, fire is not used enough in prairie management (Schramm, Wilhelm, Packard, personal communications). This is surprising considering the importance and cost effectiveness of this management tool. New prairie restorations or neglected prairie remnants should be burnt yearly for up to a decade. Once a mature healthy system is established, the prairie plants will prevent most of the encroachment of undesirable species. At this stage fire should be applied on a rotation of 1–3 years. A conservative manager may wish to burn half of the area each year, providing unburned refugia for insects (Schramm 1990).

Changing the timing of the prescribed burn is also being considered in Illinois prairie management. In the past, prescribed burns have usually been conducted in the early spring, but most historical accounts of prairie fires in Illinois indicate that presettlement burning

frequently occurred in the fall (McClain 1992). Proponents argue that fall fires burn hotter and will carry over a larger area, while opponents say early spring fires are important for preserving winter wildlife cover and protecting against soil erosion. Both sides, however, agree that fire in either the fall or the spring is better than no fire at all. For more information on fall versus spring burning, see Whisenant and Uresk (1989), Henderson (1990), and Schramm (1990).

Prairie Restoration

Habitat restoration has been heralded as a viable technique for the amelioration of habitat loss through development. Several prairie restorations have been successful in establishing high biological, or at least botanical, diversity on formerly agricultural or degraded land. A good example is the Schulenberg Prairie at the Morton Arboretum in Lisle. Initially, volunteers were used extensively to grow plants from seed in a greenhouse, hand-plant the material on the site, and control non-native species. Some direct seeding has been done on additional parts of the site, and there has been considerable species enrichment through transplanting. Another diverse restoration is the Doris L. Westfall Prairie in Forest Glen Preserve (Campbell and Westfall 1991). Over 120 species of prairie plants native to Vermilion County are found in this site, and most have been introduced through repeated seeding.

Most prairie restorations, however, contain at most one-fourth to one-half of the plant species that would be found in a natural prairie remnant of comparable size. Several factors are responsible. Because of cost and labor limitations, most prairie restorations are planted with a one-time seeding. Relatively few species are included in the seeding mixes, a number of species included in the mixes rarely succeed from seed, and follow-up species enrichment does not take place. For example, very good records have been kept of the diversity of various restoration projects begun at Fermilab in DuPage County, Illinois. Tracts at Fermilab that have been under prairie restoration management for over 10 years only show a fraction of the floristic diversity of the native prairie. Likewise, the insect diversity on these restorations tends to be uniformly low (Panzer, personal communication).

The success of prairie restorations seems to depend largely upon the techniques used to restore the prairie (McClain 1986). Restorations can be conducted through a process of seeding, planting seedlings, or transferring sod from intact prairie. It appears that transplanting sod increases the likelihood of success in establishing soil microorganisms and a fuller complement of vascular flora. The lack of a full diversity of prairie plants, however, should not discourage the use of restoration techniques to increase the total area of prairie within Illinois. At present, we do not yet know whether these restored sites will eventually become more diverse. Also, over the short term these restoration sites provide habitat for species that are becoming increasingly rare in the state.

HIGHWAY CORRIDORS

With funding from the Illinois Environmental Protection Fund Commission, the Natural History Survey is investigating ways that the extensive Illinois highway corridor system can provide habit for the species that constitute the rich native biodiversity of Illinois. This project is called Corridors for Tomorrow. The Illinois Interstate highway system is the third largest in the nation, with about 1,900 miles of corridors, 370 interchanges, and 31 open or proposed rest areas. Associated with this system is about 135,000 acres of land. These corridors are in state ownership and are subject to far less pressure from economic and ownership changes than most land in the state.

Following traditional highway management practices, most right-of-way is currently planted with species not native to Illinois or even the United States. Management practices have also emphasized cyclic patterns of disturbance, such as herbicide use and mowing. As economic restrictions have recently limited this management, and to reflect the public's growing awareness with the environment, we must reevaluate approaches to roadside design. One alternative is to use highway rights-of-way to provide much-needed habitat for the plants, birds, mammals, and insects that are part of our state's natural heritage.

Each unit in the Interstate highway system—corridors, interchanges, and rest areas—provides opportunities for the effective use of these native plant communities. The long expanses of corridors can be used for prairie grasses, more complete prairie reconstructions, designed interpretations of prairie, mass plantings of native shrubs, and scattered, clustered, or dense stands of native trees. Interchanges present excellent opportunities for the use of native plants because of their relative isolation and large size. The extensive space at interchanges will allow better development of prairies, mixed shrubs and trees, simulated woodlands, and savannas. These added habitats offer our native plants

and animals structural cover, reproductive sites, and food resources.

Revegetation will increase the average size of our habitat fragments and decrease habitat isolation by providing connecting corridors. The importance of highways as dispersal routes connecting habitat fragments has been demonstrated for small mammals. Prairie plantings would also provide habitat for many grassland birds, wintering ground for upland gamebirds and a seed source for migrating birds, and pollen, nectar and food resources for native bees, wasps, butterflies, and other insects. The overall design of highway plantings needs careful consideration to include species that cover the complete range of flowering period, from early spring to late fall, with a broad fruiting period. Plants are largely dependent on insects for pollination and on a wide variety of animals for seed dispersal. A phenologically complete habitat provides optimum conditions for the greatest diversity of native insects, birds, and small mammals.

Landscape designs are being developed to provide better interpretations of biodiversity to the motorist than would strict re-creation of native habitats. For example, a realistic prairie restoration 30 feet wide is not very dramatic at 65 miles per hour. A way to help interpret the prairie for the motorist is to dissect it and show the component parts on a large scale. The components could be presented in mass plantings of showy species at intervals along the corridors. This presentation would provide an attractive public educational opportunity.

Perhaps the most practical human benefit from revegetation efforts in Illinois will be the improvement of the quality of our environment. We are all concerned about how human activities are modifying the very nature of our world. Climatic changes, toxic pollution, erosion, diminishing water quality, food shortage, and depletion of our non-renewable energy resources affect everyone's life. Diverse highway corridors act as buffers between agricultural and urban development and the existing native habitats of Illinois. These revegetation buffers soak up pollution, capture and store carbon dioxide, filter and dilute dust and exhaust pollution, retard erosion and loss of top soil, and retard siltation of our streams, rivers, and lakes. Reduction of maintenance practices, including mowing and herbicide application, will significantly reduce our state's use of energy and toxic chemicals. Highway landscaping with native species also contributes to the scenic beauty of Illinois and leaves motorists with a favorable image. An Illinois revegetation program will also help activate local interest in environmental issues and stimulate grassroot efforts for an environmentally sound Illinois.

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FORESTS

SUMMARY

A review of some of the trends apparent in Illinois forests over the past several decades reveals the following conclusions:

1. Total forest area is now increasing statewide due to several incentive and educational programs. The only exception may be in the south-central portion of the state, where fragmentation is apparently continuing.

2. Timber volume increased by 40% between 1962 and 1985. Volumes for most forest types have increased substantially, with the exception of elm-ash-cottonwood, which has decreased because of Dutch elm disease. Net annual growth, by contrast, was 30% higher in 1962 than in 1985, showing the aging nature (with concomitant slowing of growth rates) of our secondary forests.

3. The composition of the forests is changing dramatically. Maple species are replacing much of the oak-hickory forests as well as dominating new forestland succeeding from abandoned pastures. The oak-hickory forests are not being regenerated and will thus continue to decrease in area and importance.

4. Because of the dramatic increases in volume, the Illinois forests served as a large carbon sink from 1962 to 1985. The annual sequestration of carbon into Illinois forests is estimated to be 1.37 million metric tons, enough to counteract about 2.65% of the total carbon emissions being put into the atmosphere by the people of Illinois.

5. Most of the forests are associated with the state's stream network. In the south-central portion of the state, 78% of the forestland lies within 300 m of the streams.

6. The biological diversity of the state is being carried, in large part, by the forests. Over half of the native flora and over half of the threatened or endangered flora are found in the state's forests. According to one index, over 75% of the wildlife habitat in the state is found within the forests.

7. The invasion of exotic species is one of the most serious problems facing Illinois forests, and this problem continues to increase both in severity and scope. Exotic plants reduce within-site plant diversity, as well as reducing habitat quality for native fauna. Exotic insect pests and pathogens threaten Illinois populations of several key species of trees.

8. Forest habitat loss and fragmentation have reduced the ability of Illinois forests to maintain biological diversity in numerous ways. The effects of habitat loss and fragmentation include (a) loss of appropriate habitat for species requiring large tracts of forest (e.g., many large mammals and birds); (b) invasion by exotic species, particularly weedy plants, of the forest interior and habitat edges; (c) increases in potentially damaging native species (e.g., deer) that use habitat edges and threaten biological diversity within sites; (d) increased probability of chance extinction of small, isolated populations; and (e) decreased gene flow between isolated populations, increasing the likelihood of inbreeding depression for both flora and fauna.

9. Effects of pollution (NO_2, SO_2, ozone depletion) and global warming on forest health in Illinois appear minor relative to changes in forest health in the northeastern United States and Europe, where forest decline is severe. Habitat fragmentation, exotic species, and plant diseases, however, are having a negative impact on forest biodiversity in Illinois. Past timber harvest practices may also have had a long-lasting negative impact on forest quality. Although Illinois currently does not have forest decline problems, all of these factors may contribute to decreased forest health in the future.

FOREST AREA

Historical Changes: 1820–1985

Illinois forests have undergone drastic changes in the decades since European settlement. In 1820, 13.8 million acres of forest existed in the state (Figure 1). Only 31% (4.26 million acres) of the forest area present in 1820 remained in 1980 (Figure 1), and essentially all (except for about 11,600 acres) of the

present forests are considered to be secondary forest. Illinois ranks 49th (Iowa is 50th) in the percentage of land remaining in its original vegetation type (11%) (Klopatek et al. 1979). The pattern and rate of deforestation in the latter part of the last century rivals, and even surpasses, that of tropical deforestation occurring today.

Nonetheless, forest area has recently been increasing in the state. The lowest estimate of forest area in the state was made by Telford (1926), which estimated forest area to be only 3.02 million acres, compared to estimates of 4.0 million acres in 1948 (U.S. Forest Service, 1949), 4.04 million acres in 1962 (Essex and Gansner, 1965, updated by Hahn 1987), and 4.26 million in 1985 (Hahn 1987). Forest area increased by 10% from 1962 through 1985, due primarily to reduced cattle production in the state during that period with subsequent conversion of hayland and pastures to secondary forest. Recent farm programs, such as the Conservation Reserve Program and the Illinois Forestry Development Act, have provided incentive to convert additional, marginal acres to forestland.

When the state is evaluated according to five ecologically based regions (Figure 2), the changes in forest area since 1820 show similar patterns: major declines in forest area occurred between 1820 and 1924, with slow increases in area since 1924 (Figure 3). The only region to lose forest area between 1962 and 1985 was the South-Central Region, a group of 31 counties south of the Shelbyville moraine and north of the Shawnee Hills. In this region, Bond, Clark, Clinton, Fayette, Franklin, Gallatin, Hamilton, Jasper, Lawrence, Marion, Montgomery, Perry, Richland, Shelby, St. Clair, Wabash, and Wayne counties each lost more than 5,000 acres of forestland. Counties in other regions losing more than 5,000 acres were Alexander and Massac from the Southern Unglaciated Region, Greene from the Western Region, and Lake from the Northern Region. By contrast, 38 counties gained more than 5,000 acres of forestland during this interim,

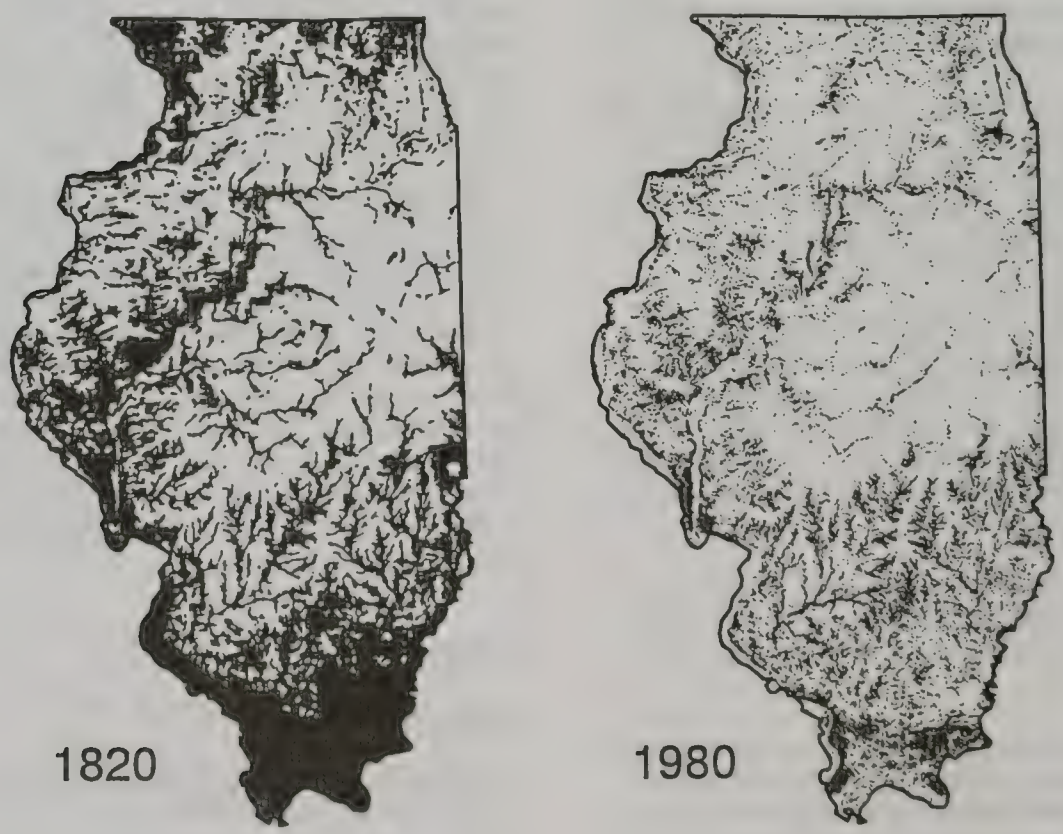


Figure 1. Forests in Illinois in 1820 (left) and 1980 (right). Sources: Anderson 1970 and U.S. Geological Survey land-use data, 1973–1981.

mostly from the northern two-thirds of the state (9 of 12 counties from the Northern Region, 11 of 31 counties from the Grand Prairie Region, 14 of 21 counties from the Western Region, 1 of 31 counties in the South-Central Region, and 3 of 7 counties in the Southern Unglaciated Region). County-by-county trends in forest area between 1962 and 1985 are shown in Figure 4. Clearly, forest area generally increased in northern counties (especially those along the major river systems), while significant forest losses occurred in the southern portion of the state (with the exception of Shawnee National Forest counties).

Forest Pattern and Trends in the South-Central Region

To better understand the temporal and spatial patterns of forest patches in the South-Central Region, one 1990 Landsat TM scene, which covered all of 13 counties, was analyzed in detail (Figure 5). This region was selected for intensive study because it was the only region where forest loss occurred from 1962 to 1985. The satellite data were at a resolution of 98 x 98 ft (30 m x 30 m), so that forest patches as small as approximately 0.25 acre (0.1 ha) could be identified . The

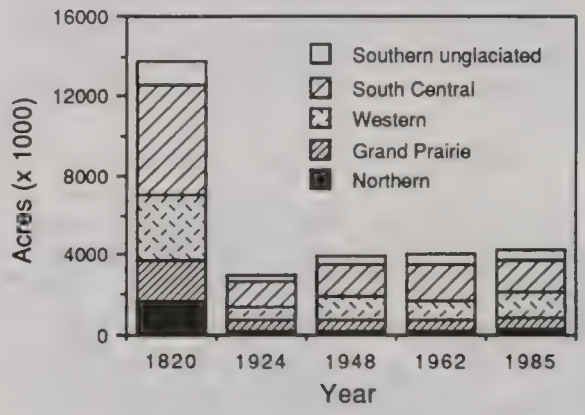


Figure 3. Changes in forest area by region, 1820–1985.

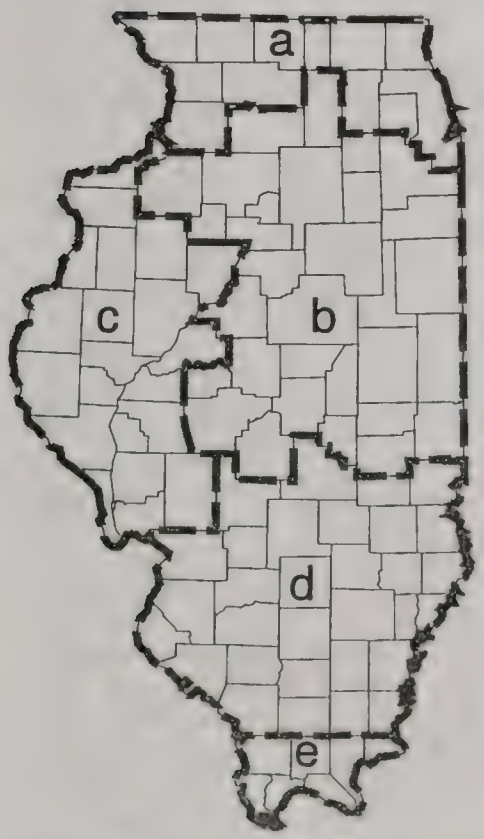


Figure 2. Illinois regions: (a) Northern, (b) Grand Prairie, (c) Western, (d) South Central, and (e) Southern Unglaciated.

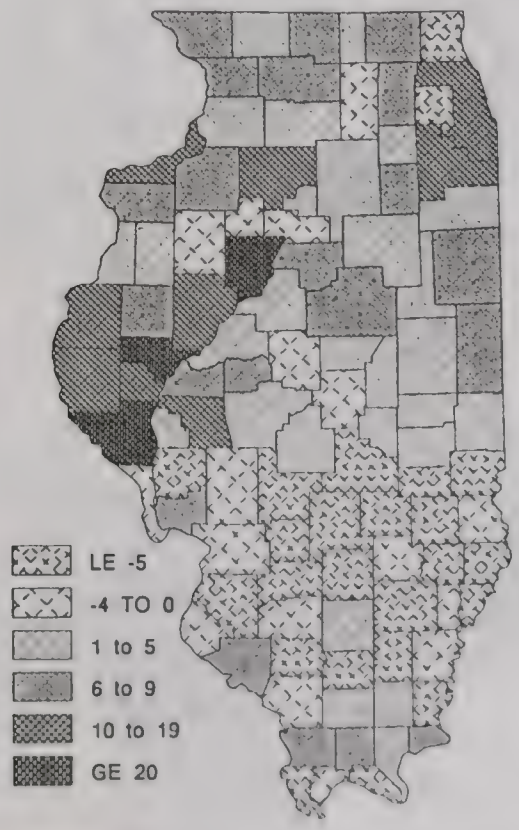


Figure 4. Changes in forest area by county (acres x 1000), 1962–1985.

distribution of the forest is highly fragmented, and the forest is primarily located adjacent to streams.

Direct comparisons of the 1990 satellite image assessment and a 1985 estimate by the U.S. Forest Service (a sampling procedure) are not reliable because the two studies used completely different methodologies. Still, it is useful to estimate forest area and fragmentation amount in this portion of the state. U.S. Forest Service data are summarized as "commercial" forestland, where commercial forestland is defined as all forested habitat that is not publicly held or explicitly withheld from potential timber harvest (state parks and nature preserves); this covers 95% of all forestland in Illinois.

The forest area for the 13 counties as determined from the 1990 satellite data was substantially lower than the 1985 or 1962 estimates of the U.S. Forest Service (Figure 6). It is likely, however, that many of the changes can be attributed to variation in the methodology; the classification of the satellite data did not include some areas that were interpreted by the U.S.

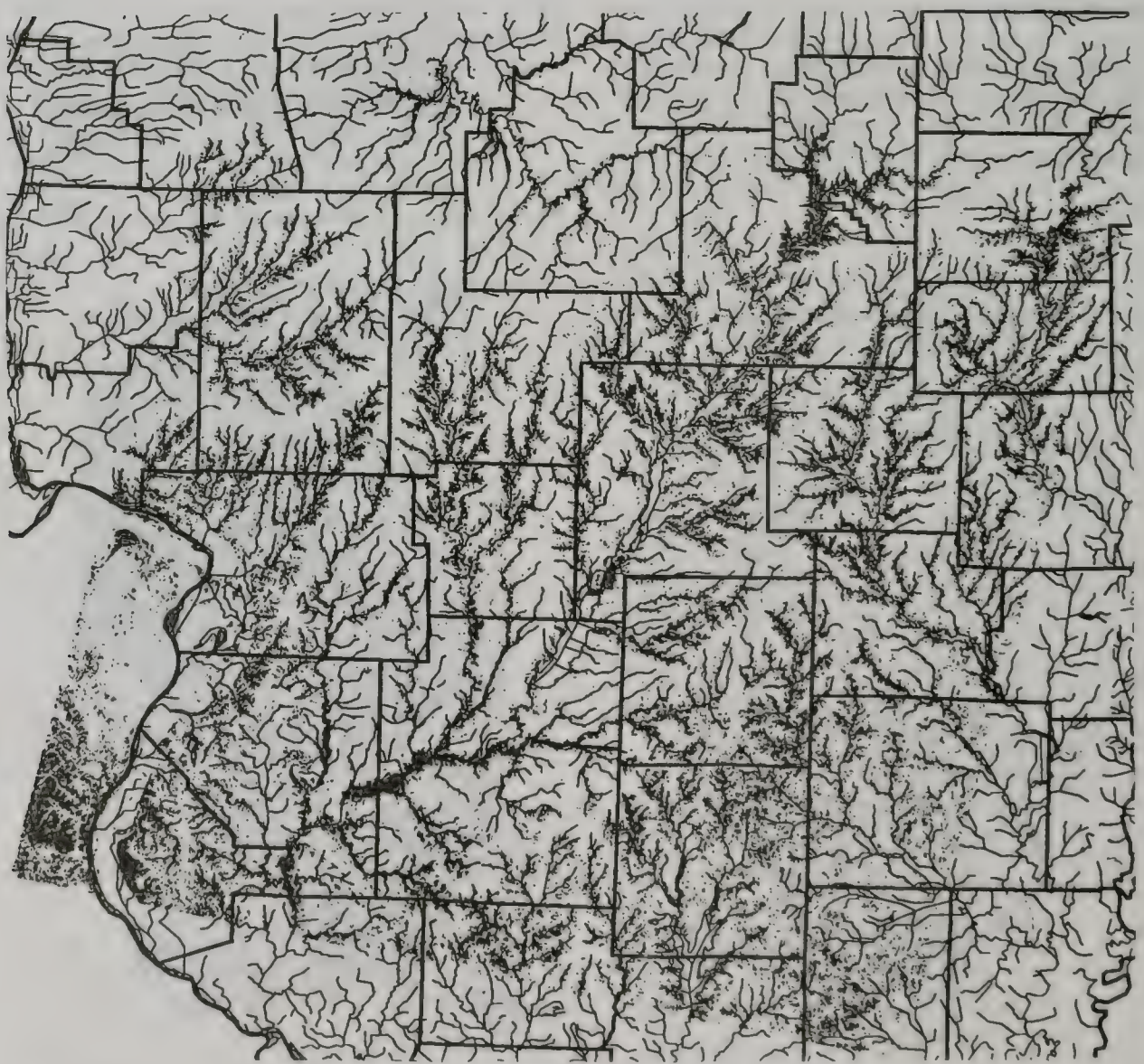


Figure 5. Satellite image classification (from 1990) of forests for 13-county region in south-central Illinois, showing that most remaining forest stands are along streams and rivers.

Forest Service as forest in 1985. Still, the region of satellite analysis was the one portion of the state that showed a decline in forest area between 1962 and 1985 (Figures 3 and 4), and the decreasing trend might have continued from 1985 to 1990.

The satellite data also show the fragmented nature of the forests. Fragmentation of forest habitat generally has negative implications for wildlife, especially for neotropical migrant birds that need large blocks of uninterrupted forest for successful nesting. As large tracts of forest are broken into small, isolated woodlots, more forest edge is created and more opportunities exist for edge-adapted species, most commonly the cowbird, to invade the area and prevent adequate nesting for many forest songbirds. The vast majority of forest parcels in this region are less than 1 acre (0.4 ha) (Figure 7). These small forest patches would be areas (ranging to as small as about 65 x 65 ft, or 20 x 20 m) where trees dominate, even in backyards, so that the 98 x 98 ft (30 x 30 m) pixel would classify as forest in the satellite imagery. Parcels greater than 40 acres (16 ha) are much less common, with the number of parcels of this size in each county ranging from 95 in St. Clair County to 269 in Fayette County. When one considers the larger forest patch sizes that may be needed to support forest interior birds (e.g., 600 acres or 243 ha), the numbers drop to a range of 3 in Montgomery County to 17 in Fayette County.

When evaluated on a per-unit area basis (the density of forest patches per township-sized area of 36 square miles, or 93.2 km^2), one can better understand the "population dynamics" of the forest patches. The number of forest patches under 1 acre (0.4 ha) per township-sized area ranged from 211 to 770 in St. Clair and Jefferson counties, respectively. The data also show the paucity of large forest patches in the region. A summation of all patches greater than 40 acres (16 ha) reveals that only 5.2 patches of this size can be found, on average, in each township of St. Clair County, ranging up to 14.1 patches per township in Jefferson County. Jefferson County originally (ca. 1820) was 73% forest, at least 20% higher than any of the other counties in the study area (Iverson et al. 1989); it therefore would be expected to have the highest density of forest patches remaining. For the entire 13-county area, there were an average of 10.1 forest patches per township, only about one patch for each 4 square miles (10 km^2).

A cautious comparison of these data can be made to data from a different study. Using U.S. Geological Survey land-use data dating from 1974 to 1979, Iverson et al. (1989) found that the density of forest patches greater than 40 acres ranged from 7.1 to 9.7 per township in this region. Although the data are not completely comparable, they suggest a slight increase in patch density from the 1970s to 1990. This trend could have occurred in at least two ways: (1) some additional patches of at least 40 acres could have been added to the pool due to regrowth or aggregation of smaller patches, or (2) some quite large patches could have been split into two or more medium-sized (but

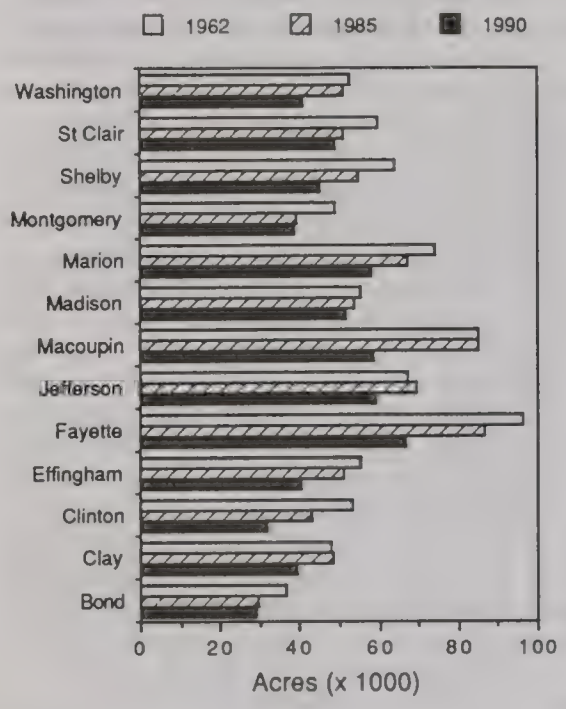


Figure 6. Number of acres of forest in 13 counties in south-central Illinois, 1962–1990.

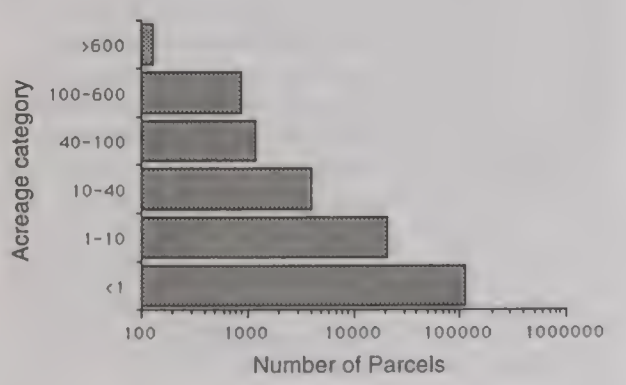


Figure 7. Number of forested parcels in 13 counties in south-central Illinois, as detected by satellite in 1990.

still > 40 acres) patches due to continued fragmentation. Based on the data presented here and a reevaluation of the data in Iverson et al. (1989), the latter is most likely the case.

By overlaying the forest classification from satellite data with the streams from the area (1:100,000 digital line graph files), we can estimate the proportions of the Illinois forests that lie within certain distances of the streams. For this area, no less than 78% of the forests exist within 984 ft (300 m) of the streams (Figure 8). A full 22% of the forests are found within 98 ft (30 m) of the streams. An evaluation of the distribution of forests circa 1820 (Figure 1) shows that the close proximity of streams and forest in this region has historically been the case; the streams were efficient fire barriers that reduced the frequency of fires. The data also show the massive elimination of upland forests that were deemed more "suitable" for other uses. These data provide at least circumstantial evidence of the importance of forests in maintaining stream health, and the reverse is also true (see Osborne and Wiley 1988).

This original research on 13 counties in south-central Illinois can be summarized as follows: (1) in the absence of more frequent U.S. Forest Service inventories (which would be very valuable), satellite data can be used to understand the distribution of forestlands across the state (however, calibration and further research is needed in this area); (2) forest area changes in the region are unclear, but forest area is probably not increasing as in the rest of the state; (3) there is extraordinary fragmentation of the forests; and (4) forests occur mainly near streams and rivers.

Ownership Patterns of Illinois Forests

More than 90% (3.64 million acres) of the commercial forests in Illinois are privately owned, mostly by farmers and other individuals (Figure 9). The remaining 10% is publicly owned, primarily by the federal government in the form of the Shawnee National Forest. The Cooperative Extension Service of the U.S. Department of Agriculture estimated that Illinois had 169,073 private forestland owners, each of whom owned an average of 21.5 acres of forest. The primary reasons for forest ownership given by the holders of small parcels were wildlife habitat and aesthetic value (Young et al. 1984); income was of greater importance for those who owned large forest parcels (McCurdy and Mercker 1986).

FOREST PLANT DIVERSITY

Vascular Plant Diversity

The Illinois Plant Information Network (ILPIN) contains habitat and distribution data for the flora of Illinois (Iverson and Ketzner 1988). Using ILPIN, one can assess the distribution of forest vascular plant species within Illinois. Mapping the number of species of forest plants by county reveals that the areas of highest diversity are the Chicago region, western Illinois, and the very southern tip of Illinois (Figure 10). This geographic distribution corresponds to the general regions of maximum forest cover (Figure 1), but climate and geomorphic variations are also responsible for the biogeography of the state. The wide range in latitude from north to south accounts for a considerable range in climate and geomorphic conditions, and subsequently, a remarkable diversity of habitats. The presence of many species with affinities toward the northern temperate flora results in increased diversity

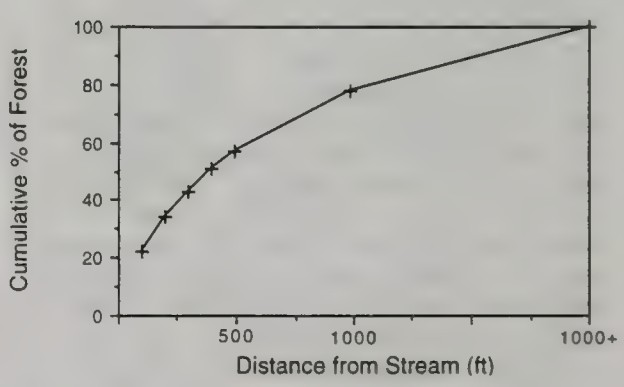


Figure 8. Cumulative percentage of forest within various distances from streams in 13 counties in south-central Illinois.

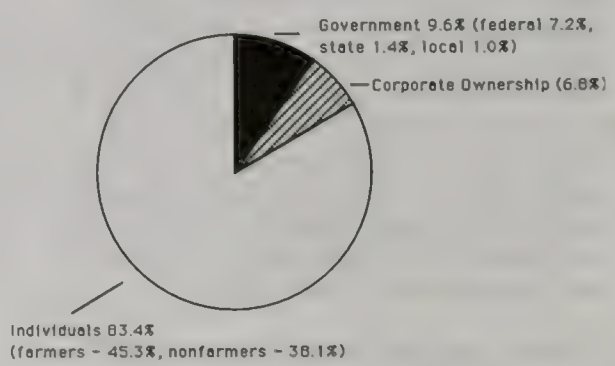


Figure 9. Ownership of Illinois forests, 1985.

in the northern counties, while species characteristic of the Appalachian flora increase diversity in the southern counties (Figure 10). Likewise, plants with affinities toward southern floodplains increase the species diversity along the major waterways in the western counties (Figure 10). This general pattern of regions with high biological diversity is reflected in both wetland and prairie species as well (see corresponding chapters in this report). Over 250 species of trees (native and introduced) have been recorded in Illinois. Southern counties have the greatest variety: Jackson has 145 species, Pope 129, and Union 128; several northeastern counties also have high diversity due to varied landscapes and escaped cultivars from the Chicago region (Figure 10). In addition to the trees, there are 284 taxa of shrubs (some of which can also be called trees) and 47 taxa of lianas reported for the state. Overall, 508 taxa of woody plants have been recorded, including 138 introduced species.

Illinois' forests are exceptionally rich in nonwoody taxa as well. Including the woody species, there are 1,581 forest-associated plant taxa in the state, 1,414 (89%) of which are native. Jackson County—a botanically rich southern county that is also the home of Southern Illinois University, from which numerous botanical surveys have been conducted—has 954 forest-associated native taxa on record, whereas Warren County in the northwest (not close to a botanical center) has had only 262 taxa recorded. In general, higher botanical diversity occurs in the southern counties, with species having affinity to the Appalachian flora, and in the northern counties, with species rich in the northern temperate flora. As one might expect, relatively lower diversities of forest-associated species are naturally found in the counties formerly dominated by prairie.

With diversity at its highest in the northern and southern counties, it is not surprising that the highest concentrations of threatened and endangered species, as well as exotic species, occur in the northern and southern counties (Figure 10). One additional pattern is noteworthy among these figures on the distribution of floral diversity in Illinois. There are a great many more non-native species in any given region than there are threatened and endangered species (Figure 10). This observation suggests that the exotic species problem may be bigger than the threatened and endangered species problem with respect to conserving biological diversity within Illinois. Legislative action has assured some level of protection against further losses in native species diversity. The lack of such legislative structure regarding exotics gives very little protection from further introductions of exotic species, whether intentional or accidental (see below).

Recent Changes in Forest Composition

The composition of Illinois forests has changed dramatically over the past three decades. Today, about one-half of the commercial forest acreage is oak-hickory, one-fourth is maple-beech (almost exclusively sugar maple), and one-sixth is elm-ash-soft maple (Figure 11). Together, the remaining forest types (white-red-jack pine, loblolly-shortleaf pine, oak-pine, and oak-gum-cypress) account for an additional 217,000 acres of commercial forestland. In 1962, however, there was much more acreage of oak-hickory and elm-ash-cottonwood and very little area dominated by the maple-beech type. Since 1962, the maples have increased by a factor of 41, whereas the oaks have been reduced 14% and the elms have been cut in half (Figure 11). The loss of oak-hickory forest is largely explained by the "maple take-over," in which mature oak-hickory forests are unable to regenerate themselves because the tree seedlings are intolerant of excessive shade in the absence of fire. By contrast, maple seedlings thrive in the shady environment and are positioned for rapid growth and dominance once the overstory is removed or dies. The reduction of elm-ash-soft maple is largely due to the effects of Dutch elm disease and the conversion to agriculture of bottomland forests that once supported these trees (especially in the South-Central Region).

These trends are also evident by the age class distribution of the major forest types (Figure 12). The oak-hickory type dominates in the older age classes, whereas the maple-beech type dominates in the younger age classes; as time passes, maples will continue to increase in dominance. The age class distributions within forest types have changed between 1962 and 1985. Both the elm-ash-cottonwood and oak-hickory forests have matured during this 23-year period (Figure 13). In contrast, the oak-gum-cypress has shifted from primarily older stands to primarily younger stands (Figure 13). Maple-beech forests, while increasing dramatically in total acreage (Figure 11), have not shifted in the age distribution of stands (Figure 13). This pattern is likely to change in the future as these stands mature. Finally, pine has not shifted its relative distribution between older and younger stands during the 23-year census interval (Figure 13).

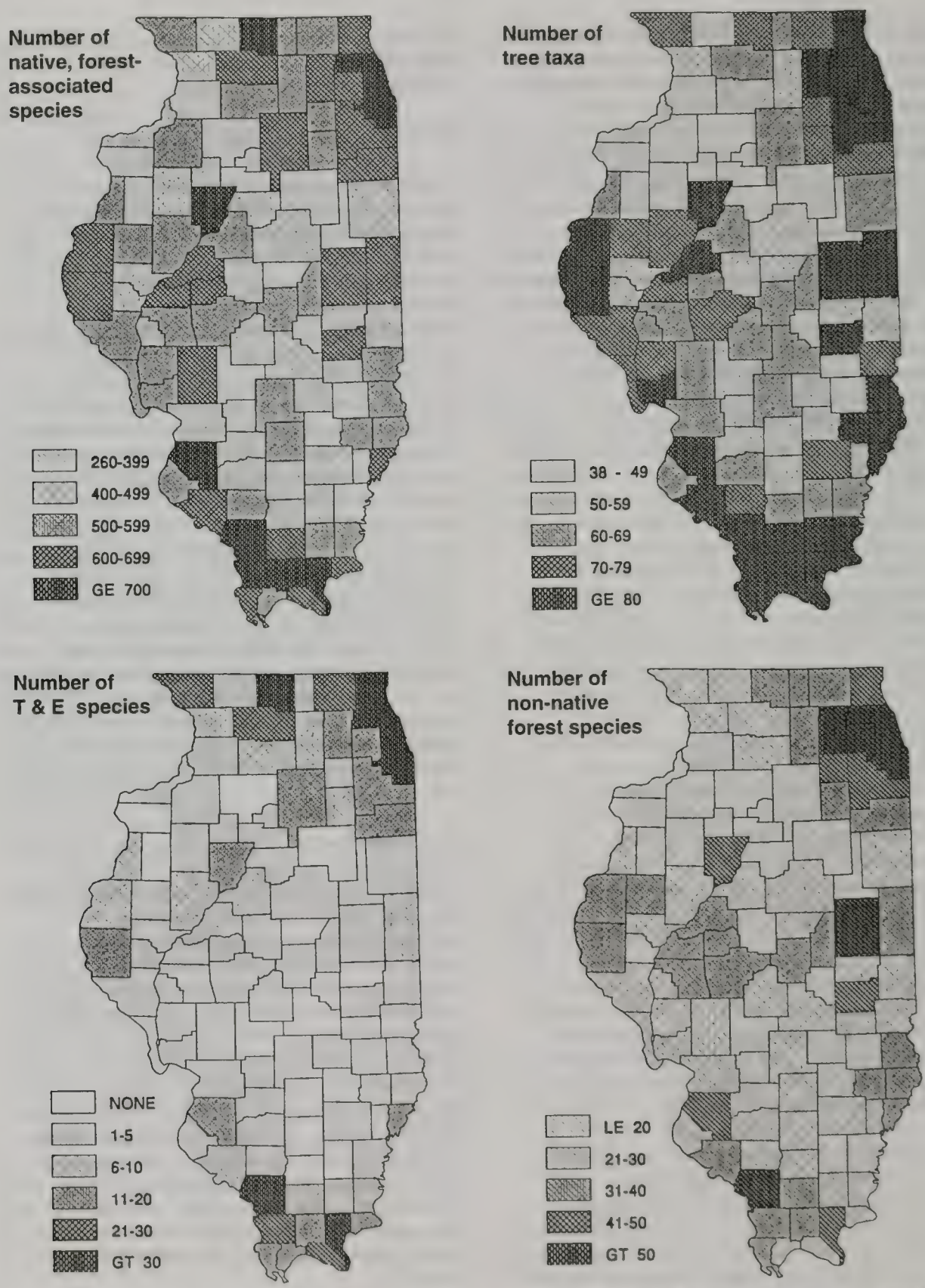


Figure 10. The total number of forest-associated, native species (top left), number of tree taxa (top right), number of threatened and endangered (T & E) species (bottom left), and number of non-native forest species (bottom right) in each Illinois county as recorded by the Illinois Plant Information Network.

Tree Abundance

An estimated 1.93 billion trees stood in Illinois commercial forests in 1985 (Hahn 1987). Surprisingly, the most common tree type was the elm, with 344 million trees (Figure 14). These are not the American elm, however, which was devastated by Dutch elm disease, but the slippery, or red, elm, which rarely attains a large stature but is very common in the understory. Overall, white oaks (99 million), red oaks (136 million), hickories (185 million), hard maples (117 million), and soft maples (91 million) were very abundant. Based on these trends and the dynamics of forest regeneration in the absence of fire, the future will show an increase in maple abundance and concomitant decreases in oak and hickory abundance.

Timber Volume, Growth, Harvest, and Mortality

The total volume of growing stock in 1985 was 4.8 billion cubic feet, 40% greater than the 3.4 billion cubic feet reported for 1962 (Hahn 1987). Net volume estimates for 1985 showed the prominence of oak and hickory in commercial forests, with considerable amounts of ash, black walnut, cottonwood, elm, maple, and sycamore as well (Figure 15). The 1985 volumes averaged 47.4 million cubic feet per county or 1,200 cubic feet per acre of commercial forestland in the state.

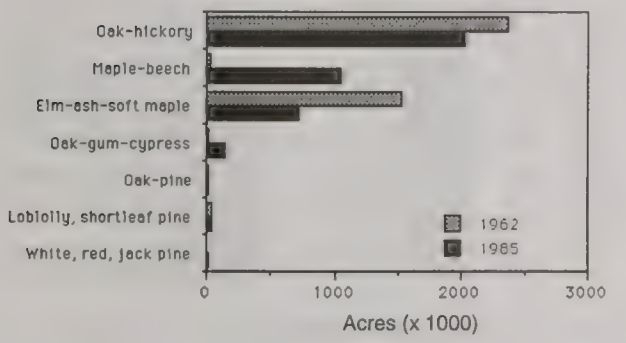


Figure 11. Composition of Illinois commercial forests, 1962 and 1985.

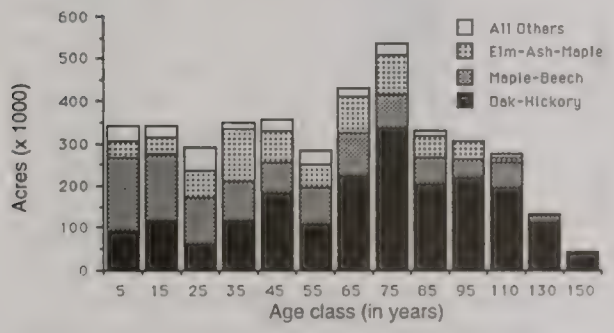


Figure 12. Acreage by age class of the major forest types in Illinois, 1985.

The trends in volume since 1948, by species group, are shown in Figure 16. For all groups except elm, there was a dramatic increase in volume since 1962. The elms have declined since 1948 due to bottomland conversion to agriculture and Dutch elm disease. White and red oaks and black walnut had total volume decreases from 1948 to 1962 (due to a drop in forestland area because volume per acre increased slightly during the period), but showed increases in volume from 1962 to 1985 (due to a large increase in volume per acre in spite of a decrease in oak area during this period). The other types—hickories, maples, and ashes—have increased in volume since 1948.

Net annual growth was estimated in 1985 (Hahn 1987) to be 96 million cubic feet of growing stock or 437 million board feet of sawtimber. Over 42% of net annual sawtimber growth was accounted for by oaks, with another 10% from soft maple, 6.3% from ashes, 3.7% from black cherry, 3.3% from hard maple, and 3.2% from black walnut. Only elm and black ash showed negative growth rates between 1962 and 1985, attributable to Dutch elm disease and the clearing of bottomlands.

Compared to the 1985 data, the 1962 inventory showed a 30% higher level of annual growth (125 million cubic feet of growing stock). The lower annual growth and higher volumes in 1985 compared to 1962 indicate that growth has outstripped removals in the past several decades and that growth rates may be declining due to maturing forests (Figure 16). The trends in volume during 1962–1985, when evaluated by county, show large percentage increases for all northern and central counties (except Whiteside) but generally lower or even negative volume changes for south-central counties (Figure 17). This trend can be primarily linked to the area changes for the region as discussed previously (see Figure 4).

Illinois ranks fifth in the nation in demand for wood but 32nd in the production of wood. Although we import much of the wood we need from other states, 14% of the wood harvested in Illinois is processed in neighboring states. This processed wood is often then imported back into Illinois. Currently, the annual growth of timber (96 million cubic feet) exceeds timber

removals (68.6 million cubic feet), so that accumulation of volume statewide will continue, barring major harvest changes, into the near future.

An enormous quantity of firewood—nearly 2 million cords a year—is harvested from Illinois forests. About 43% of the trees used (harvested or salvaged) in a given year in Illinois are used for firewood! The demand for firewood does not currently present a major threat to our forests, however, because 75% of the firewood cut is taken from dead trees. The major harvest of fuelwood takes place in the heavily populated northeastern counties (Figure 18). Trees cut for sawlogs, by contrast, are primarily found in the southern half of the state (Figure 19), with the major counties cutting sawlogs in 1983 being Franklin, Fulton, Jackson, and White (with over 6 million board feet per county).

To summarize, biomass and annual harvest have increased statewide during the past 23 years while annual growth has decreased (Figure 20), possibly as a result of maturing stands (Figure 13). Mortality rates during this period have increased dramatically (Figure 20). Although the sources of this mortality cannot be ascertained in many cases, the leading known causes of mortality are insect damage and pathogens, which account for 38% of the mortality (Table 1). The

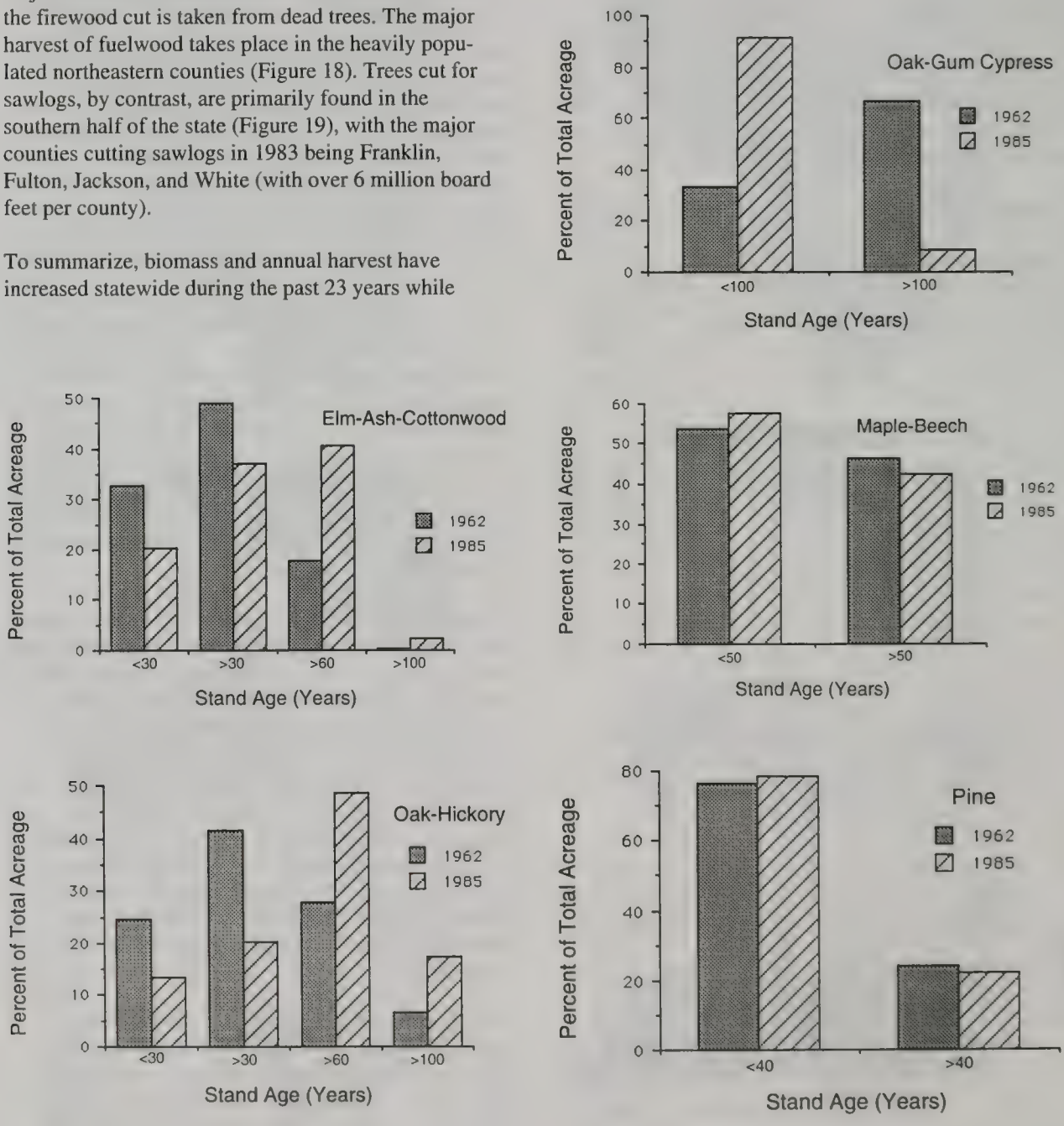


Figure 13. Age structure of various forest types in 1962 and 1985. Source: Hahn 1987.

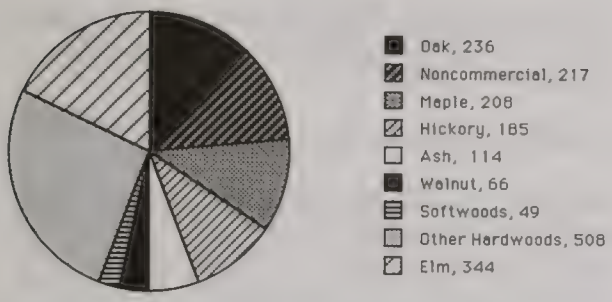


Figure 14. Number (in millions) of live trees of various types in Illinois commercial forestland, 1985.

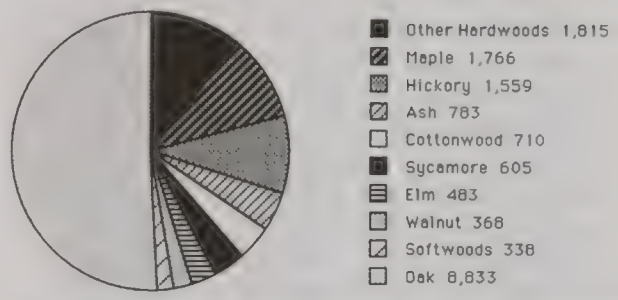


Figure 15. Volume (in million board feet) of various types of trees in Illinois commercial forestland, 1985. Total volume of sawtimber was 17.5 billion board feet.

majority of insect and pathogen mortality can be traced to two sources: (1) introduced pests spreading through the region (such as Dutch elm disease) or (2) decreased resistance to disease and herbivores as a result of environmental stress (such as the red spruce decline in the northeastern United States or the general forest decline in northern Europe). Examining mortality patterns by species shows that elm leads all species in mortality rates (Table 1). The majority of this mortality is the result of continued spread of Dutch elm disease in Illinois. Thus, it seems likely that the observed increase in mortality rate from 1962 to 1985 may not be symptomatic of general forest decline (Figure 20) but may indicate a peak in mortality associated with a single disease spreading through the region. There appear to be no major differences in mortality rates of trees by ownership category (Table 2).

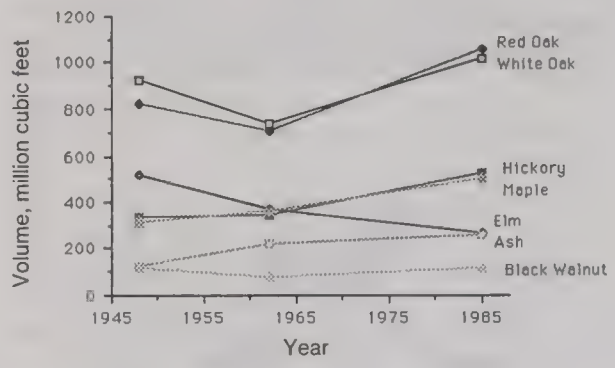


Figure 16. Trends in volume of various types of tree, 1948–1985.

Tree Health

An investigation of tree health in Illinois forests was conducted during the summer of 1992 (Iverson and Schwartz, unpublished data). For this study, the investigators followed the USDA Forest Service Forest Health Monitoring (FHM) protocol (Conkling and Byers 1992). The FHM protocol is designed to establish long-term monitoring stations from which periodic samples are collected in order to assess changes in the health and status of forests throughout the United States. The federal project is in a test phase, with current information available for only three regions (USDA Forest Service 1993, Bechtold et al. 1992). Iverson and Schwartz (unpublished data) implemented the FHM protocol in 31 forest plots across Illinois. The sites were stratified to sample each portion of the state in approximate relation to the abundance of forests within that region (Figure 21). Likewise, sampling attention was divided between upland (24 sites) and bottomland forests (7 sites) with respect to their relative abundances. Finally, although publicly held forestlands were primarily selected, the sample included six privately held woodlots.

For each sampled plot, tree composition and health were assessed. Within tree plots sapling density, seedling recruitment, and herbaceous species cover were also sampled. To assess forest health, the following measurements are collected for trees: species, size, crown diameter, crown density, crown damage, and foliage transparency. The crown health measurements (density, damage, and transparency) can indicate symptoms of disease, herbivore damage, or environmental stress. While these data are most useful in subsequent re-measurements, the initial results among species were compared to determine whether certain species are showing signs of stress. In addition, the Illinois results were compared to forest health in other regions.

The canopy health measurements demonstrate relatively low signs of damage among most species and

most categories (Table 3). The exceptions are a relatively high incidence of crown dieback in white oak (*Quercus alba*) and sugar maple (*Acer saccharum*) (Table 3). It is not clear why these species are showing these potential symptoms of stress. Likewise, silver maple (*Acer saccharinum*) and sweetgum (*Liquidambar styraciflua*) showed relatively high frequencies of low crown density (Table 3). Again, we have little information with which to interpret these data, but sweetgum is often susceptible to crown damage as a result of late spring freezes, as was the case over much the state in 1992. There did not appear to be any significant differences in tree health between upland and bottomland forests or between publicly owned versus private upland woodlands. These results also demonstrate uniformly lower levels of damage in Illinois than in comparable studies for all crown damage parameters; Illinois trees appear in good health compred to those in Southern, Mid-Atlantic and New England states (Table 3).

Herbaceous Species Diversity

The FHM study was used to measure floristic composition and diversity among Illinois forests. Three 1-m^2 quadrats were sampled for plant cover in each of four subplots at each site. The results indicated no differences in overstory or understory species richness in forests differing in ownership category (public versus private), or in upland versus lowland forests (Table 4). Despite wide variation in the mean number of understory species sampled (range: 3.0 to 13.8/m^2), understory diversity did not correlate well with general characteristics of the forest plot (e.g., overstory composition, tree density). Thus, although different forest types received different levels of management attention, no systematic differences in the ability of forest types to conserve forest health or species diversity were demonstrated. Further, this sampling

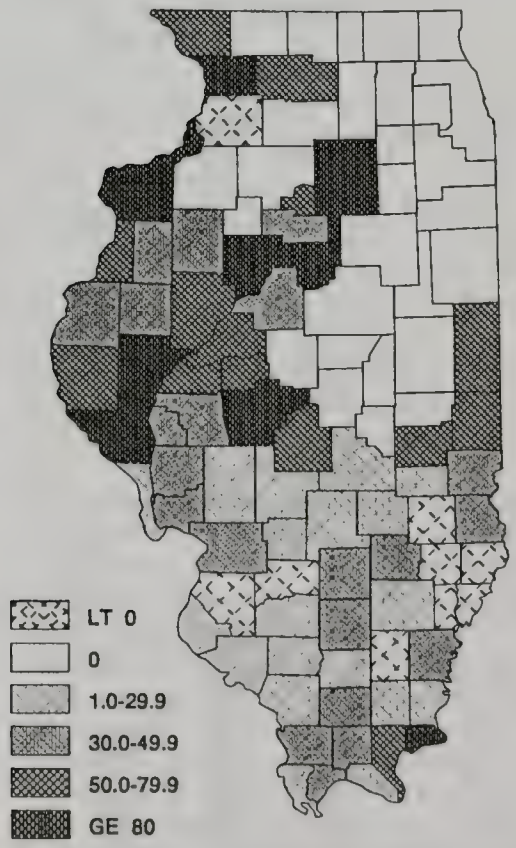


Figure 17. Changes in forest volume by county from 1962 to 1985, given in millions of cubic feet of sawtimber. [Note: for 28 counties with no coded change, no specific data were available for 1962 volumes; over all these prairie counties, however, there was a 269% increase in volume between 1962 and 1985.]

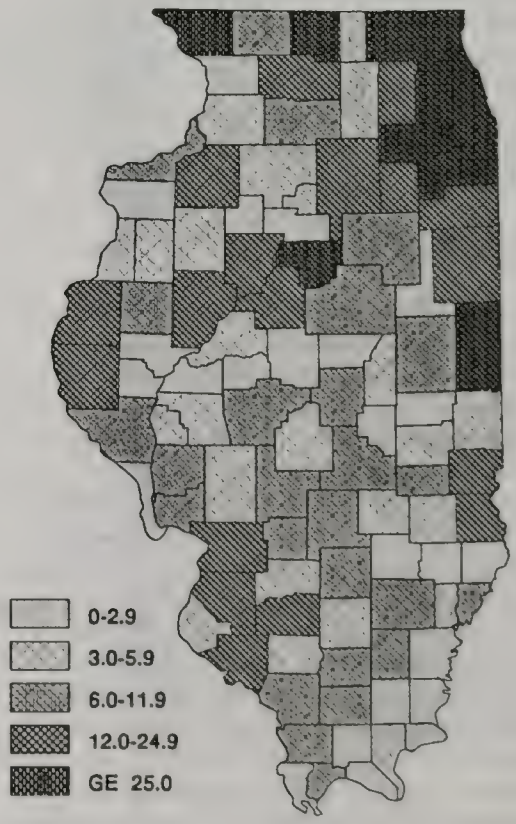


Figure 18. Number of standard cords of fuelwood (x 1000) produced in each Illinois county, 1983.

provides no specific indicators to suggest how forest diversity may be increased or maintained.

Exotic Forest Weeds

Exotic plant species in Illinois may be defined in three contexts—broad, narrow, and legal. In a broad sense, exotic species are those that did not naturally occur in Illinois before European settlement. This includes species that are common in surrounding states but were formerly not found in Illinois. At present, exotic species make up 28% of the Illinois flora. Table 5 shows the increase of exotic species in the flora over the past 146 years. From 1975 to 1992 the number of exotic species does not appear to have increased.

In the narrow sense, exotic species are all plant species not native to North America. Seventy-eight percent of the 28% of exotic species in the Illinois flora are non-North American natives; these species thus constitute about 21% of the Illinois flora.

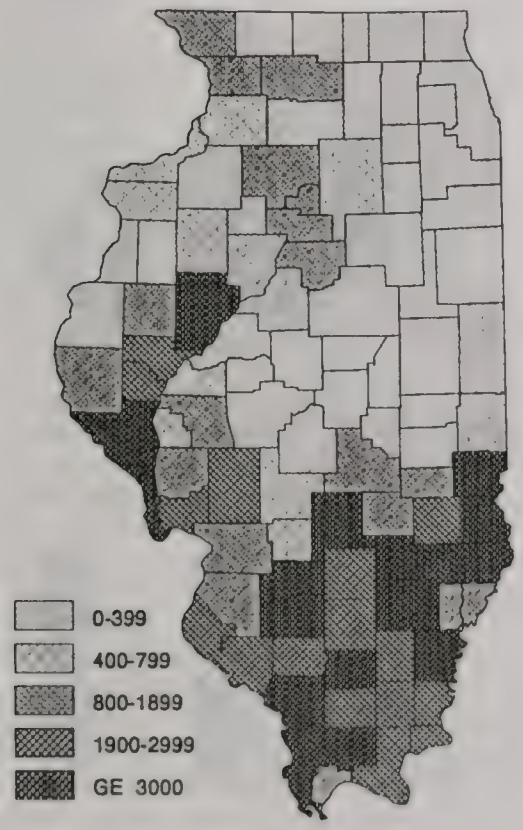


Figure 19. Sawlog production (in thousands of cubic feet) by county, 1985.

The legal definition of an exotic species in Illinois is provided by the Illinois Exotic Weed Act (IEWA) of 1988. It defines an exotic plant as "those plants not native to North America which, when planted, either spread vegetatively or naturalize and degrade natural communities, reduce the value of fish and wildlife and wildlife habitat, or threaten an Illinois endangered species." (Gould and Gould 1991). Although many species fit this description, at present only three exotic species are covered by the IEWA —Japanese honeysuckle (*Lonicera japonica* Thunb.), multiflora rose (*Rosa multiflora* Thunb.), and purple loosestrife (*Lythrum salicaria* L.).

The definition of an exotic species in the IEWA highlights some of the reasons exotic species are considered undesirable components of the Illinois flora. Some exotic species are barely able to survive in Illinois and are poorly established, but many more are widespread and aggressive in growth habit. Generally, these more successful and aggressive exotic weeds originate from an area that has a climate similar to Illinois and do well in the state in the absence of their natural pests. These exotic weeds alter the structure, species composition, and diversity of native plant communities. Table 6 lists 25 of the species that pose the most serious threat in native Illinois forest communities.

Exotic weedy shrubs are currently the most serious threat to Illinois forest communities. Often these exotic shrubs were intentionally introduced by landowners and wildlife managers. The shrubs were easy to obtain, were relatively disease- and pest-free, and reproduced rapidly. Many, such as amur honeysuckle (*Lonicera maackii* [Rupr.] Maxim.), autumn olive (*Elaeagnus umbellata* Thunb.), common buckthorn (*Rhamnus cathartica* L.), multiflora rose, glossy buckthorn (*Rhamnus frangula* L.), and tartarian honeysuckle (*Lonicera tatarica* L.) were introduced to provide food and cover for wildlife. Some exotic shrubs, such as multiflora rose, were also used to reduce erosion, provide living fences for livestock (Albaugh et al. 1977), serve as crash barriers along highways, and reduce headlight glare in the median of highways (Schery 1977). Other shrubs, such as amur honeysuckle, Japanese barberry (*Berberis thunbergii* DC.), privet (*Ligustrum obtusifolium* Sieb. & Zucc.), tartarian honeysuckle, and winged euonymus (*Euonymus alata* [Thunb.] Sieb.) were frequently planted as ornamentals in Illinois.

These shrubs vary widely in the severity and range of their invasion in our native forest communities. A few shrubs, such as common buckthorn, are presently of major concern in northern Illinois forests, while

multiflora rose is a major problem in forests throughout Illinois. Autumn olive generally does not do well in the deep shade of Illinois forests and is more commonly encountered in disturbed or weedy areas. However, it is spread by birds that regurgitate the seeds and may quickly invade newly timbered or disturbed sites. Although first released in 1963, autumn olive was not considered to spread extensively from cultivation. The Illinois Department of Conservation began producing autumn olive in 1964, and by 1982 their nurseries were distributing more than 1 million autumn olive seedlings per year (Harty 1986). The Illinois Department of Conservation no longer provides autumn olive through its seedling nursery program, and the department is currently growing only native species. Nonetheless, this species is now expected to naturalize throughout the southern two-thirds of Illinois (Ebinger 1983). Another example is winged euonymus, a native to China and Japan, which has been reported as rarely escaping from cultivation in the eastern United States (Gleason 1952). However, winged euonymus was first reported as naturalized in Illinois in 1973; some of the plants were more than 25 years old (Ebinger and Phillippe 1973). It is presently found in 13 counties in Illinois and undoubtedly occurs in many more. Unlike autumn olive, the winged euonymus can grow and reproduce in the dense shade of relatively undisturbed forest communities (Ebinger et al. 1984). Many exotic shrubs are now serious pests, and others have the potential to become major problems in Illinois forests.

Second to the shrubs as a serious threat to Illinois forest communities are woody vines. Table 6 lists four vines causing the most problems. Japanese honeysuckle, the most troublesome exotic weedy vine, was introduced into the United States as an ornamental and

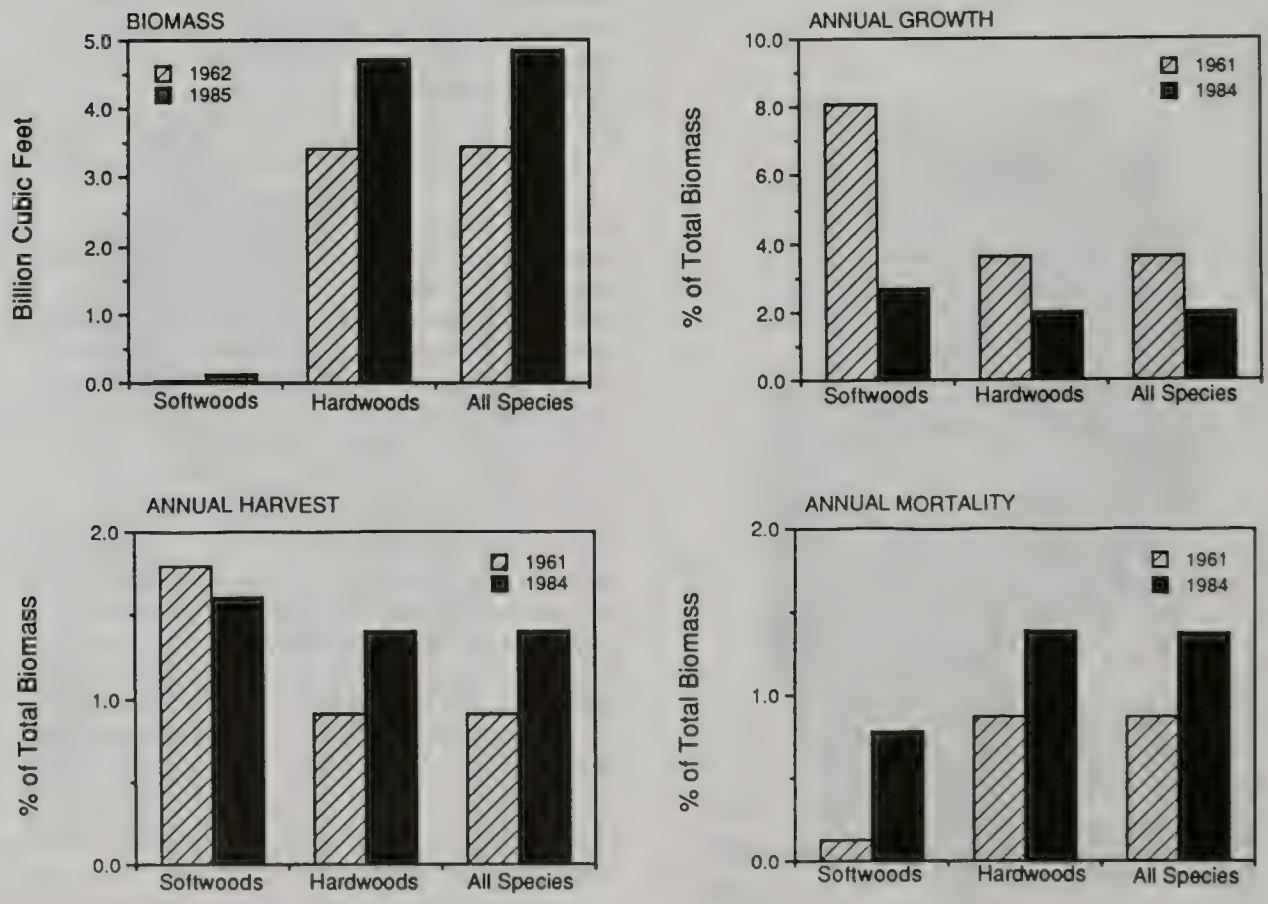


Figure 20. Biomass (top left), annual growth (top right), annual harvest (bottom left), and annual mortality (bottom right) of forest growing stock, 1961 (or 1962) and 1984. Source: Hahn 1987.

Table 1. Annual mortality rates for major tree species in Illinois. Data compiled by the U.S. Forest Service (1987).

Species	Net volume	% annual mortality	Source (%)			
			Insects	Disease	Weather	Other
White Oak	1,017,620	0.535	-	45.9	-	54.1
Red Oak	1,062,426	1.225	2.1	40.8	3.8	46.7
Hickory	522,473	1.010	24.3	15.8	8.8	51.1
Basswood	54,075	1.041	-	-	-	100.
Beech	12,096	0.405	-	-	-	100.
Hard maple	163,083	0.658	-	51.9	-	48.1
Soft maple	341,610	1.432	34.9	-	31.0	34.1
Elm	267,399	6.449	0.8	56.3	-	42.9
Ash	260,998	0.983	-	29.5	13.0	57.5
Sycamore	134,626	1.570	-	-	-	100.
Cottonwood	157,795	1.658	-	47.8	52.2	-
Willow	50,267	1.653	-	28.0	51.1	20.8
Hackberry	93,543	1.368	-	-	-	100.
Bigtooth Aspen	1,945	2.108	-	-	-	100.
River Birch	36,822	1.472	-	-	19.9	80.1
Sweetgum	45,077	1.477	-	-	-	100.
Tupelo	28,043	1.590	-	51.8	-	48.2
Black Cherry	87,658	1.629	-	74.0	-	26.0
Black Walnut	119,982	1.023	-	67.2	-	32.8
Butternut	5,712	1.173	-	-	-	100.
Yellow Poplar	51,773	1.120	-	-	-	100.
Other	203,486	1.827	-	-	-	100.
Jack Pine	702	0.285	-	-	-	100.
Red Pine	11,986	0.801	-	-	-	100.
White Pine	16,811	0.773	100.	-	-	-
Loblolly and Shortleaf Pine	64,736	0.695	- 36.9	-	63.1	
Baldcypress	8,904	1.606	- -	-	100.	
Eastern redcedar	11,359	0.607	- -	-	100.	
Other softwoods	2,995	0.534	- -	-	100.	

has been widely planted for wildlife enhancement. It provides valuable cover for bobwhite quail (*Colinus virginianus*) and turkey (*Meleargris gallopavo*), the stems and leaves serve as food for white-tail deer (*Odocoilens virginiana*), and the berries are consumed by a number of song birds (Handley 1945). Japanese honeysuckle may be found in shaded and open conditions and, despite its ornamental use and value to wildlife, is a tremendous threat to native plant species.Although it is seldom a major concern in established forests, when the forest is disturbed by natural causes such as windthrow or disease, or by human activities such as lumbering or construction, Japanese honeysuckle grows rapidly (Evers 1984). Rapid growth of this vine is a threat to rare native plant species and may modify natural succession. The vine may physically deform, bend, or eventually kill saplings, and foresters are sometimes reluctant to cut forests that have been invaded by Japanese honeysuckle because they fear the forest will not become reestablished following cutting (Little and Soanes 1967).

Table 2. Growth and mortality rates of growing stock timber by ownership category. Data expressed as a percentage of the total biomass.

Ownership class	Growth (%)	Mortality (%)
National forest	1.90	1.16
Misc. federal land	1.03	1.77
State	0.86	1.36
County and municipal	2.25	1.59
Forest industry	2.61	0.95
Farmers	1.98	1.41
Misc. private corp.	1.86	1.47
Misc. private individuals	2.12	1.33
All	1.99	1.38

Table 3. Evaluation of health (as indicated by crown density, crown dieback, and foliage transparency) of individual forest tree species in Illinois and a comparison of hardwood health in Illinois with that in other regions. Except for values for sample size, all numbers represent percentages of trees.

Health of individual species in Illinois

Crown density[1]	n	Good	Average	Poor	
White oak	77	85.7	14.3	0.0	
American elm	51	68.6	31.4	0.0	
Sugar maple	49	75.5	24.5	0.0	
Silver maple	43	65.1	32.6	2.3	
Sweetgum	28	50.0	46.4	3.6	
Black oak	28	85.7	14.3	0.0	
Black walnut	25	88.0	12.0	0.0	
Box elder	25	84.0	16.0	0.0	
Red elm	23	60.9	39.1	0.0	
Red oak	20	85.0	15.0	0.0	
Crown dieback[2]		**None**	**Light**	**Moderate**	**Severe**
White oak	77	93.5	3.9	0.0	2.6
American elm	51	96.1	2.0	2.0	0.0
Sugar maple	49	98.0	0.0	0.0	2.0
Silver maple	43	95.3	4.7	0.0	0.0
Sweetgum	28	100.0	0.0	0.0	0.0
Black oak	28	89.3	10.7	0.0	0.0
Black walnut	25	92.0	8.0	0.0	0.0
Box elder	25	76.0	20.0	4.0	0.0
Red elm	23	91.3	8.7	0.0	0.0
Red oak	20	85.0	10.0	5.0	0.0
Foliage transparency[3]		**Normal**	**Moderate**	**Severe**	
White oak	77	98.7	1.3	0.0	
American elm	51	98.0	2.0	0.0	
Sugar maple	49	100.0	0.0	0.0	
Silver maple	43	100.0	0.0	0.0	
Sweetgum	28	96.6	3.4	0.0	
Black oak	28	100.0	0.0	0.0	
Black walnut	25	100.0	0.0	0.0	
Box elder	25	96.0	4.0	0.0	
Red elm	23	100.0	0.0	0.0	
Red oak	20	100.0	0.0	0.0	

Hardwood health in Illinois compared to that in other regions

Crown density		Good	Average	Poor	
Illinois[4]	655	75.7	23.2	1.1	
Southern U.S.[5]	2746	37.9	61.3	0.8	
New England[6]	2602	54.8	41.7	3.4	
Mid-Atlantic[6]	351	68.7	30.2	1.1	
Crown dieback		**None**	**Light**	**Moderate**	**Severe**
Illinois	655	91.9	5.0	1.4	1.7
Southern U.S.	2746	85.1	13.1	1.3	0.4
New England	2602	78.4	17.3	2.9	1.4
Mid-Atlantic	351	70.1	29.3	0.6	0.0
Foliage transparency		**Normal**	**Moderate**	**Severe**	
Illinois	655	75.7	23.2	1.1	
Southern U.S.	2746	37.9	61.3	0.8	
New England	2602	54.8	41.7	3.4	
Mid-Atlantic	351	68.7	30.2	1.1	

[1] Crown denstiy class: good > 50%; average = 21–50%; poor < 20%.
[2] Crown dieback class: none = 0–5%; light = 6–20%; moderate = 21–50%; severe > 50%.
[3] Foliage transparency class: normal <30%; moderate = 31–50%; severe >50%.
[4] Data from Iverson and Schwartz, unpublished.
[5] Data from Bechtold et al. 1992.
[6] Data from Eagar and Adams 1992.

The herbaceous exotic weeds found in nearly all of the forests in Illinois include annual, biennial, and perennial herbs (Table 6). Common chickweed (*Stellaria media* [L.] Vill.) has been found in all 102 counties of Illinois. However, garlic mustard (*Alliaria petiolata* [Bieb.] Cavara & Grande) appears to be the greatest threat to Illinois forests. Introduced as a food or medicinal herb, it was first found in Cook County, Illinois, north of Chicago, in 1918. Garlic mustard readily spreads into high-quality old-growth forest and

Table 4. Mean herb diversity per square meter in forest plots sampled in 1992.

	Herb diversity	SE	n
Ownership (Uplands only)			
Public	6.53	3.1	19
Private	8.50	3.5	5
Forest type (public only)			
Upland	6.53	3.1	19
Bottomland	7.59	3.6	7

Figure 21. Locations of 31 study sites sampled to assess forest health in Illinois using the FHM sampling procedure (see text for additional explanation).

may now be found in at least 41 counties in Illinois (Schwegman 1988, Nuzzo 1991). This biennial plant produces numerous seeds and is a major threat to Illinois' woodland herbaceous flora, and to wildlife that depend on it for food and cover (Schwegman 1988). The threat of garlic mustard is particularly acute since it has only recently spread through the state (Figure 22), and populations are still expanding throughout the state.

Table 5. Percentage of alien species in the Illinois spontaneous vascular plant flora from 1846 to 1992.

Flora author	Year of publication	% alien species
S.B. Mead	1846	10.2
I.A. Lapham	1857	6.6
H.N. Patterson	1876	7.5
W.C. Flagg and T.J. Burrill	1878	10.5
G.N. Jones	1945	15.9
G.N. Jones	1950	15.9
G.N. Jones and G.D. Fuller	1955	25.0
G.S. Winterringer and R.A. Evers	1960	26.0
G.N. Jones	1963	24.7
R.M. Myers	1972	25.4
R.H. Mohlenbrock	1975	27.9
R.H. Mohlenbrock and D.M. Ladd	1978	28.7
ILPIN	1992	28.0

Source: Henry and Scott 1980.

Four problematic exotic weed trees in Illinois forests are amur maple (*Acer ginnala* Maxim.), golden-rain tree (*Koelreuteria paniculata* Laxm.), tree-of-heaven (*Ailanthus altissima* [Mill.] Swingle), and white mulberry (*Morus alba* L.). Tree-of-heaven and white mulberry are found throughout Illinois. Tree-of-heaven is especially abundant on steep slopes below the bluffs of the Illinois and Mississippi rivers. Golden-rain tree, though uncommon, has also become naturalized on steep slopes below the river bluffs north of Alton, Illinois, in Madison County. Amur maple, a native of central and northern Manchuria, northern China, and Japan is commonly planted as an ornamental throughout Illinois. This species most commonly naturalizes in open fields and prairies but occasionally occurs in open woods and potentially may become a major weed problem in the Midwest (Ebinger and McClain 1991).

Exotic weeds make up more than one-fifth of Illinois' flora, and they affect forest communities. The distur-

Table 6. The 25 exotic weeds that pose the greatest threat to Illinois forests.

Growth habit	Common name	Scientific name
Herbs	Garlic mustard	*Alliaria petiolata* Bieb.
	Ground ivy	*Glechoma hederacea* L. var. *micrantha*
	Sericea lespedeza	*Lespedeza cuneata* Dum.-Cours.
	Moneywort	*Lysimachia nummularia* L.
	Eulalia	*Microstegium vimineum* Trin.
	Beefsteak plant	*Perilla frutescens* L.
	Creeping smartweed	*Polygonum cespitosum* var. *longisetum* DeBruyn
	Self-heal	*Prunella vulgaris* L.
	Common chickweed	*Stellaria media* L.
Shrubs	Japanese barberry	*Berberis thunbergii* DC.
	Autumn olive	*Elaeagnus umbellata* Thunb.
	Winged euonymus	*Euonymus alata* Thunb.
	Privet	*Ligustrum obtusifolium* Sieb. & Zucc.
	Amur honeysuckle	*Lonicera maackii* Rupr.
	Tartarian honeysuckle	*Lonicera tatarica* L.
	Common buckthorn	*Rhamnus cathartica* L.
	Glossy buckthorn	*Rhamnus frangula* L.
	Multiflora rose	*Rosa multiflora* Thunb.
Trees	Amur maple	*Acer ginnala* Maxim.
	Tree-of-heaven	*Ailanthus altissima* Mill.
	Golden-rain tree	*Koelreuteria paniculata* Laxm.
	White mulberry	*Morus alba* L.
Vines	Round-leaved bittersweet	*Celastrus orbiculatus* Thunb.
	Climbing euonymus	*Euonymus fortunei* Turcz.
	Japanese honeysuckle	*Lonicera japonica* Thunb.
	Kudzu-vine	*Pueraria lobata* Willd.

Sources: L.R. Iverson, L.R. Phillippe, and J. Schwegman, unpublished data.

bance is quite variable in degree and may affect any stratum. In areas severely invaded by exotic shrubs and vines, succession may be altered so the structure of the forest is drastically changed. Exotic weeds also alter the biodiversity of Illinois forests. Japanese honeysuckle and multiflora rose are two exotic weeds recognized by the IEWA that pose serious threats to the forests of Illinois, and for these species, "It shall be unlawful for any person, corporation, political subdivision, agency or department of the State to buy, sell, offer for sale, distribute or plant seeds, plants, or plant parts, of exotic weeds without a permit issued by the Department of Conservation" (Gould and Gould 1991). Exotic weeds are a serious problem in Illinois forests, and recovery depends on the appropriate actions taken and enforced, such as those stated in the Illinois Exotic Weed Act.

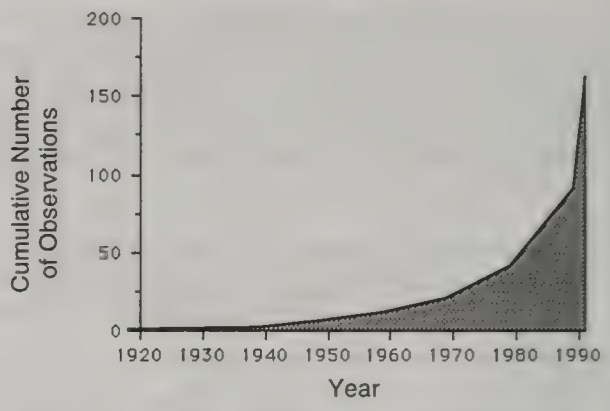


*Figure 22. Spread of garlic mustard (*Alliaria petiolata*), an exotic weedy pest species, through Illinois, as demonstrated by the cumulative number of occurrences by decade. Data are from Nuzzo (1993) and are based on herbarium collections, sight observations, and literature references.*

Threatened and Endangered Forest Plants

Threatened and endangered plants make up 17% of our native Illinois flora. Threatened plants are those likely to become endangered within the foreseeable future, and endangered plants are those in danger of extirpation from Illinois. Three hundred fifty-six taxa are listed as threatened or endangered under the Illinois Endangered Species Act (Herkert 1991). Forty-nine percent of these taxa have been found in the forests of Illinois. Thirty-three threatened taxa are listed in Table 7, and 142 endangered taxa are listed in Table 8.

Of the 172 vascular plant families in the Illinois flora (Mohlenbrock 1986), 32% are represented by these threatened and endangered forest taxa. The sedge family (Cyperaceae) has the most taxa (22), followed by the grass family (Poaceae) with 14, and the aster (Asteraceae) and orchid (Orchidaceae) families with 10 each.

Fourteen percent of the Illinois genera of vascular plants are represented by these threatened and endangered forest taxa. Sedge (*Carex*) is the most represented taxa (18), followed by panic grasses (*Panicum*) with 5, and grape ferns (*Botrychium*) and bluegrasses (*Poa*) with 4 each.

Most of these threatened and endangered species are at the edge of their natural distribution. Forty-four percent have primarily north or northeastern affinities, 31% have primarily south or southeastern affinities, 20% have primarily eastern affinities, and the remaining 5% have western, southwestern, or midwestern affinities. These species include 17 trees, 20 shrubs, 6 woody vines, 19 ferns and fern allies, 13 annual or biennial herbs, and 99 perennial herbs.

Of the 175 threatened and endangered taxa in the forests of Illinois, 15 listed as state endangered have not been seen in the past 20 years. These species are Price's groundnut (*Apios priceana* Robins), screwstem (*Bartonia paniculata* [Michx.] Muhl.), dwarf grape fern (*Botrychium simplex* E. Hitchc.), lined sedge (*Carex striatula* Michx.), spotted wintergreen (*Chimaphila maculata* [L.] Pursh), finger dog-shade (*Cynosciadium digitatum* DC.), moccasin flower (*Cypripedium acaule* Ait.), northern cranesbill (*Geranium bicknellii* Britt.), cow wheat (*Melampyrum lineare* Desr.), long-leaved panic grass (*Panicum longifolium* Torr.), white mountain mint (*Pycnanthemum albescens* Torr. & Gray), round-leaved shinleaf (*Pyrola americana* Sweet), goldenrod (*Solidago arguta* Ait.), nodding trillium (*Trillium cernuum* L.), and deerberry (*Vaccinium stamineum* L.).

Two Illinois state-endangered species, Price's groundnut and small whorled pogonia (*Iostria medeoloides* [Pursh] Raf.), are also federally listed species. Price's groundnut, a perennial herbaceous vine, is a federally threatened species, which means it is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Price's groundnut is known only from Alabama, Illinois, Kentucky, Mississippi, and Tennessee. In Illinois, Price's groundnut was collected in Union County in 1941. Its collection location has been repeatedly searched, but Price's groundnut has not been relocated in Illinois (Bowles et al. 1991). Small whorled pogonia, a perennial herb, is a federally

endangered species, which means it is in danger of extinction or of extirpation from a significant portion of its range. Although small whorled pogonia is known from a number of states, it is often found in only small numbers. In Illinois, for example, small whorled pogonia is known from a single population in Randolph County (Herkert 1991).

About 50 taxa formerly known from Illinois are thought to be extirpated from the state (Page and Jeffords 1991). Twelve are forest species: eight monocots and four dicots. The two flowering plant families with the most extirpated species are the grasses with four and the orchids with three.

The monocots are drooping wood reed (*Cinna latifolia* [Trev.] Griseb.), bluebead lily (*Clintonia borealis* [Ait.] Raf.), brown plume grass (*Erianthus brevibarbis* Michx.), adder's mouth orchid (*Malaxis unifoia* Michx.), rice grasses (*Oryzopsis asperifolia* Michx. and *Oryzopsis pungens* [Torr.] Hitchc.), Hooker's orchid (*Platanthera hookeri* Torr.), and round-leaved orchid (*Platanthera orbiculata* [Pursh] Torr.). The four dicots are trailing arbutus (*Epigaea repens* L. var. *glabrifolia* Fern.), twinflower (*Linnaea borealis* L. ssp. *americana* [Forbes] Hulten), flowering wintergreen (*Polygala paucifolia* Willd.), and false bugbane (*Troutvetteria caroliniansis* [Walt.] Vail).

Six species (bluebead lily , trailing arbutus, twinflower, rice grass, round-leaved orchid, and flowering wintergreen) are northern Illinois taxa, one (Hooker's orchid) is a northern and western Illinois taxon, one (drooping wood reed) is a northern and southern Illinois taxon, three (adder's mouth orchid, rice grass, false bugbane)

Table 7. Threatened vascular plants in Illinois forests. All taxa are perennial unless otherwise stated.

	Scientific name	Common name	Growth habit
Ferns	*Botrychium multifidum* (Gmel.) Rupr.	Northern grape fern	Evergreen
	Asplenium bradleyi D.D. Eat.	Bradley's spleenwort	Evergreen
	Asplenium resiliens Kunze	Black spleenwort	Evergreen
	Dennstaedtia punctilobula (Michx.)	Hay-scented fern	Deciduous
Gymnosperms	*Thuja occidentalis* L.	Arbor vitae	Tree
	Larix laricina (DuRoi)	Tamarack	Tree
Dicots	*Aristolochia serpentaria* L. var. *hastata* (Nutt.)	Virginia snakeroot	Herb
	Matelea obliqua (Jacq.)	Climbing milkweed	Herb; vine
	Aster furcatus Burgess	Forked aster	Herb
	Aster schreberi Nees	Schreber's aster	Herb
	Aster undulatus L.	Wavy-leaved aster	Herb
	Circium carolinianum (Walt.)	Carolina thistle	Herb; biennial
	Helianthus angustifolius L.	Narrow-leaved sunflower	Herb
	Solidago sciaphila Steele	Cliff goldenrod	Herb
	Lonicera flava Sims	Yellow honeysuckle	Woody vine
	Sambucus pubens Michx.	Red-berried elder	Shrub
	Euonymus americanus L.	Strawberry bush	Shrub
	Lathyrus ochroleucus Hook.	Pale vetchling	Herb
	Quercus phellos L.	Willow oak	Tree
	Quercus prinus L.	Rock chestnut oak	Tree
	Trientalis borealis Raf.	Star flower	Herb
	Rubus pubescens Raf.	Dwarf raspberry	Shrub
	Sullivantia renifolia Rosendahl	Sullivantia	Herb
	Besseya bullii (Eat.) Rydb.	Kitten tails	Herb
	Styrax americana Lam.	Storax	Shrub
	Viola conspersa Reichenb.	Dog violet	Herb
Monocots	*Scirpus polyphullus* Vahl	Bulrush	Herb
	Polygonatum pubescens (Willd.)	Downy Solomon's seal	Herb
	Stenanthium gramineum (Ker)	Grass-leaved lily	Herb
	Trillium viride Beck	Green trillium	Herb
	Veratrum woodii Robbins	False hellebore	Herb
	Corallorhiza maculata Raf.	Spotted coral-root orchid	Herb
	Oryzopsis racemosa (J.E. Smith)	Rice grass	Herb

Table 8. Endangered vascular plants in Illinois forests. All taxa are perennial unless otherwise stated.

	Scientific name	Common name	Growth habit
Fern allies	*Equisetum pratense* Ehrh.	Meadow horsetail	Deciduous
	Equisetum scirpoides Michx.	Dwarf scouring rush	Evergreen
	Equisetum sylvaticum L.	Horsetail	Deciduous
	Lycopodium dendroideum Michx.	Ground pine	Evergreen
	Lycopodium clavatum L.	Running pine	Evergreen
Ferns	*Botrychium biternatum* (Sav.)	Southern grape fern	Evergreen
	Botrychium matricariaefolium A. Br.	Daisyleaf grape fern	Deciduous
	Botrychium simplex E. Hitchc.	Dwarf grape fern	Deciduous
	Cystopteris laurentiana (Weath.) Blasd.	Laurentian fragile fern	Deciduous
	Dryopteris celsa (Wm. Palmer) Small	Logfern	Deciduous
	Gymnocarpium dryopteris (L.) Newm.	Oak fern	Deciduous
	Gymnocarpium robertianum (Hoffm.) Newn.	Scented oak fern	Deciduous
	Thelypteris noveboracensis (L.) Nieuwl.	New York fern	Deciduous
	Thelypteris phegopteris (L.) Slosson	Long beech fern	Deciduous
	Woodsia ilvensis (L.) R. Br.	Rusty woodsia	Deciduous
Gymnosperms	*Pinus echinata* Mill.	Shortleaf pine	Tree
	Pinus resinosa Ait.	Red pine	Tree
Dicots	*Justicia ovata* (Walt.) Lindau	Water willow	Herb
	Adoxa moschatellina L.	Moschatel	Herb
	Iresine rhizomatosa Standl.	Bloodleaf	Herb
	Conioselinum chinense (L.) BSP	Hemlock parsley	Herb
	Cynosciadium digitatum DC.	Finger dog-shade	Herb
	Ptilimnium costatum (Ell.) Raf.	Mock Bishop's weed	Herb; annual
	Ptilimnium nuttallii (DC.) Britt.	Mock Bishop's weed	Herb; annual
	Matelea decipiens (Alex.) Woods	Climbing milkweed	Herb; vine
	Eupatorium incarnatum Walt.	Thoroughwort	Herb
	Lactuca hirsuta Muhl.	Wild lettuce	Herb; biennial
	Melanthera nivea (L.) Small	White melanthera	Herb
	Solidago arguta Ait.	Goldenrod	Herb
	Berberis canadensis P. Mill.	Allegheny barberry	Shrub
	Betula alleghaniensis Britt.	Yellow birch	Tree
	Betula populifolia Marsh.	Gray birch	Tree
	Hackelia americana (Gray) Fern.	Stickseed	Herb
	Lonicera dioica L. var. *glaucescens* Rydb.	Red honeysuckle	Woody vine
	Viburnum molle Michx.	Arrowwood	Shrub
	Stellaria pubera Michx.	Great chickweed	Herb
	Cornus canadensis L.	Bunchberry	Herb
	Corylus cornuta Marsh.	Beaked hazelnut	Shrub
	Melothria pendula L.	Squirting cucumber	Herb; annual vine
	Gaultheria procumbens L.	Wintergreen	Subshrub
	Vaccinium stamineum L.	Deerberry	Shrub
	Amorpha nitens Boyn.	Smooth false indigo	Shrub
	Apios priceana Robins	Price's groundnut	Herb; vine
	Astragalus crassicarpus Nutt. var. *trichocalyx*	Large ground plum	Herb
	Cladastris lutea (Michx. f.) K. Koch	Yellowwood	Tree
	Dioclea multiflora (Torr. & Gray)	Boykin's dioclea	Herb; vine
	Trifolium reflexum L.	Buffalo clover	Herb; annual/biennial
	Castanea dentata (Marsh.) Borkh.	American chestnut	Tree
	Quercus nuttallii Palmer	Nuttall's oak	Tree
	Bartonia paniculata (Michx.) Muhl.	Screwstem	Herb
	Geranium bicknellii Britt.	Northern cranesbill	Herb; annual/biennial
	Carya pallida (Ashe) Engl. & Graebn.	Pale hickory	Tree
	Pycnanthemum albescens Torr. & Gray	White mountain mint	Herb
	Pycnanthemum torrei Benth.	Mountain mint	Herb
	Synandra hispidula (Michx.) Baill.	Hairy synandra	Herb; annual/biennial

Table 8 (continued)

	Scientific name	Common name	Growth habit
	Circaea alpina L.	Small enchanter's nightshade	Herb
	Oxalis illinoensis Schwegman	Illinois wood sorrel	Herb
	Corydalis aurea Willd.	Golden corydalis	Herb; biennial
	Plantago cordata Lam.	Heart-leaved plantain	Herb
	Lysimachia fraseri Duby	Loosestrife	Herb
	Lysimachia radicans Hook.	Creeping loosestrife	Herb
	Chimaphila maculata (L.) Pursh	Spotted wintergreen	Herb
	Chimaphila umbellata (L.) Bart.	Pipsissewa	Herb
	Pyrola americana Sweet	Round-leaved shinleaf	Herb
	Cimicifuga americana Michx.	American bugbane	Herb
	Cimicifuga racemosa (L.) Nutt.	False bugbane	Herb
	Clematis crispa L.	Blue jasmine	Woody vine
	Clematis occidentalis (Hornem.) DC.	Mountain clematis	Woody vine
	Clematis viorna L.	Leatherflower	Woody vine
	Berchemia scandens (Hill) K. Koch	Supple-jack	Woody vine
	Amelanchier interior Nielsen	Shadbush	Shrub
	Amelanchier sanguinea (Pursh) DC.	Shadbush	Shrub
	Malus angustifolia (Ait.) Michx.	Narrow-leaved crabapple	Tree
	Rosa acicularis Lindl.	Rose	Shrub
	Rubus enslenii Tratt.	Arching dewberry	Shrub
	Rubus odoratus L.	Purple-flowering raspberry	Shrub
	Sorbus americana Marsh.	American mountain ash	Tree
	Waldsteinia fragarioides (Micxh.) Tratt.	Barrens strawberry	Herb
	Populus balsamifera L.	Balsam poplar	Tree
	Bumelia lanuginosa (Michx.) Pers.	Wooly buckthorn	Shrub
	Ribes hirtellum Michx.	Northern gooseberry	Shrub
	Saxifraga virginiensis Michx.	Early saxifrage	Herb
	Collinsia violacea Nutt.	Violet collinsia	Herb; annual
	Melampyrum lineare Desr.	Cow wheat	Herb; annual
	Penstemon brevisepalus Pennell	Short-sepaled beard tongue	Herb
	Halesia carolina L.	Silverbell tree	Shrub
	Styrax grandifolia Ait.	Bigleaf snowbell bush	Shrub
	Tilia heterophylla Vent.	White basswood	Tree
	Planera aquatica (Walt.) J.F. Gmel.	Water elm	Shrub
	Ulmus thomasii Sarg.	Rock elm	Tree
	Urtica chamaedryoides Pursh	Nettle	Herb; annual
	Viola canadensis L.	Canadian violet	Herb
	Viola incognita Brainerd	Hairy white violet	Herb
Monocots	*Sagittaria longirostra* (Micheli) J.G. Sm.	Arrowhead	Herb
	Carex alata Torr. & Gray	Winged sedge	Herb
	Carex brunnescens (Pers.) Poir.	Brownish sedge	Herb
	Carex canescens L. var. *disjuncta* Fern.	Sedge	Herb
	Carex communis Bailey	Fibrous-rooted sedge	Herb
	Carex decomposita Muhl.	Cypress-knee sedge	Herb
	Carex gigantea Rudge	Large sedge	Herb
	Carex intumescens Rudge	Swollen sedge	Herb
	Carex laxiculmis Schwein.	Spreading sedge	Herb
	Carex nigromarginata Schwein.	Black-edged sedge	Herb
	Carex oxylepis Torr. & Hook.	Sharp-scaled sedge	Herb
	Carex physorhyncha Liebm.	Bellow's bead sedge	Herb
	Carex prasina Wahlenb.	Drooping sedge	Herb
	Carex reniformis (Bailey) Small	Reniform sedge	Herb
	Carex striatula Michx.	Lined sedge	Herb
	Carex styloflexa Buckl.	Bent sedge	Herb
	Carex tuckermanii Boott	Tuckerman's sedge	Herb
	Carex willdenowii Schkuhr	Willdenow's sedge	Herb

Table 8 (continued)

Scientific name	Common name	Growth habit
Carex woodii Dewey	Pretty sedge	Herb
Cyperus lancastriensis Porter	Galingale	Herb
Fimbristylis annua (All.) Roem. & Schult.	Baldwin's fimbristylis	Herb; annual
Scirpus verecundus Fern.	Bashful bulrush	Herb
Luzula acuminata Raf.	Hairy woodrush	Herb
Lilium superbum L.	Turk's cap lily	Herb
Medeola virginiana L.	Indian cucumber root	Herb
Trillium cernuum L.	Nodding trillium	Herb
Trillium erectum L.	Ill-scented trillium	Herb
Cypripedium acaule Ait.	Moccasin flower	Herb
Cypripedium calceolus L. var. *parviflorum* (Salisb.)	Small yellow lady's slipper	Herb
Cypripedium reginae Walt.	Showy lady's slipper	Herb
Hexastylis spicata (Walt.) Barnh.	Crested coralroot orchid	Herb
Isotria medeoloides (Pursh) Raf.	Small whorled pogonia	Herb
Isotria verticillata (Willd.) Raf.	Whorled pogonia	Herb
Platanthera clavellata (Michx.) Luer	Wood orchid	Herb
Platanthera flava (L.) Lindl. var flava	Tubercled orchid	Herb
Platanthera psycodes (L.) Lindl.	Purple-fringed orchid	Herb
Glyceria arkansana Fern.	Arkansas manna-grass	Herb
Gymnopogon ambiguus (Michx.) BSP.	Beard grass	Herb
Milum effusum L.	Millet grass	Herb
Panicum joorii Vasey	Panic grass	Herb
Panicum longifolium Torr.	Long-leaved panic grass	Herb
Panicum ravenelii Scribn. & Merr.	Ravenel's grass	Herb
Panicum stipitatum Nash	Tall flat panic grass	Herb
Panicum yadkinense Ashe	Panic grass	Herb
Poa alsodes Gray	Grove bluegrass	Herb
Poa autumnalis Muhl.	Autumn bluegrass	Herb
Poa languida A.S. Hitchc.	Weak bluegrass	Herb
Poa wolfii Scribn.	Wolf's bluegrass	Herb
Schizachne purpurascens (Torr.) Swallen	False melic grass	Herb

are west-central Illinois taxa, and one (brown plume grass) is a southern Illinois taxon. All of these species are more common outside Illinois.

FOREST ANIMALS

Trends in Wildlife Habitat

Illinois forests provide the major habitat for more than 420 vertebrate species, and losses in the quality and quantity of that habitat severely affect wildlife populations (Illinois Wildlife Habitat Commission 1985). Of the more than 420 vertebrates listed as occurring in Illinois by the Illinois Fish and Wildlife Information System (IFWIS–Illinois Department of Conservation/ Illinois Natural History Survey), 82.5% of the mammals, 62.8% of birds, and 79.7% of the amphibians and reptiles require forested habitat for a portion of their life cycle. Clearly, forests are an important component of maintaining vertebrate diversity in Illinois. A more fine-tuned method of summarizing the value of Illinois wildlife habitat is based on land use. Complete details are presented in Graber and Graber (1976), and revised calculations based on current data are given in Iverson et al. (1989). The habitat evaluation index devised by Graber and Graber is based on the relative amount of a particular habitat type within a given area, the availability of that habitat type within the state or region, the changing availability of that habitat, and the "cost" of a given habitat measured in years required to replace the ecosystem. A summary of habitat factors (which sum to the habitat evaluation index) for Illinois as a whole, as of 1985, is presented in Table 9. By this calculation, over three-quarters of the wildlife habitat (88 of 115.73 habitat factor points) is derived from forests. Elm-ash-cottonwood rates highest because this forest type has been disappearing so quickly over the past two decades (Figure 11). Oak-hickory values would be higher except that numbers in older age classes are increasing

as secondary forests mature, even though numbers in younger age classes are decreasing (Figure 11). A very minor rating was earned by maple-beech because this forest type has increased so dramatically in recent years (Figure 9). Habitat factor scores were generally much more favorable for wildlife habitat in the southern half of the state, which has more forests. In fact, the total habitat factor scores for the south region were twice those of the central region, with the north region being in between (Iverson et al. 1989).

By comparing the habitat factor scores obtained by Iverson et al. (1989) for 1985 data to those of Graber and Graber (1976) for 1973 data, one can evaluate the temporal trends in habitat and the role of forestland in those changes. This evaluation was possible for three regions of the state—north, central, and south (caution is advised in this comparison, however, because the three regions do not exactly match geographically). It was not possible to directly compare the habitat scores between dates because of slight variations in the methodology. However, by calculating the percentage of the habitat factor occupied by each land type for the two dates, one can evaluate relative contributions to habitat by each land type over time (Figure 23). Total contributions of forestland to habitat can also be calculated. For example, in the north, the cumulative percentage from forest was 53.4% in 1973 and 65.3% in 1985—a 22% increase in relative habitat from forests in that region (Figure 23). The increase is mostly due to large increases in relative habitat factors for the elm-ash-cottonwood and pine types and a decrease in the marsh habitat factor. In the central region, relative habitat increased from 71.6% to 76.1% (Figure 23), while in the south region, relative habitat decreased from 88% to 84% (Figure 23). In all regions, there were increases in relative habitat factors for elm-ash-cottonwood because the type decreased in area by nearly 50% during that time period (Figure 13). Oak-gum-cypress, likewise, increased in all regions (Figure 23) as a result of increasing availability in younger age classes (Figure 11). Pine scores increased in the northern region (Figure 23) because its availability increased, especially in the older (> 40 year) age class.

In contrast, all regions showed a decrease in relative habitat value for the oak-hickory type and the maple-

Table 9. Habitat factors for Illinois, 1985, calculated according to Graber and Graber (1976).

Land type		Habitat factor	% of wildlife habitat
Forest	Pine	5.70	4.9
	Oak-hickory	30.07	26.0
	Oak-gum-cypress	11.97	10.3
	Elm-ash-cottonwood	40.19	34.7
	Maple-beech	0.14	0.1
Subtotal			76.0
Nonforest	Cropland	0.29	0.3
	Pasture/hayland	10.01	8.7
	Prairie	1.46	1.3
	Marsh	15.28	13.2
	Water	0.38	0.3
	Urban, residential	0.03	0.0
	Fallow	0.19	0.2
Subtotal			24.0
Total		115.73	100.0

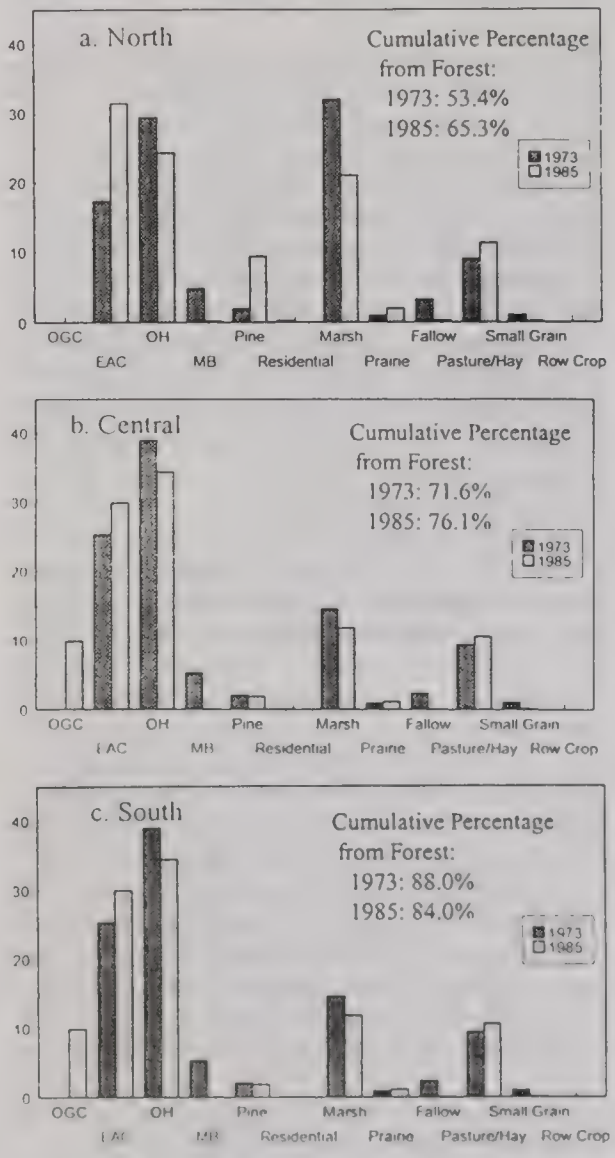


Figure 23. Relative habitat factors for three regions in Illinois in 1973 and 1985. OGC = oak-gum-cypress, EAC = elm-ash-cottonwood, OH = oak-hickory, MB = maple-beech.

beech type, but for different reasons. The oak-hickory type decreased because regeneration is not occurring, resulting in a loss of acreage (to maple) (Figure 11); habitat factor scores were especially reduced in the young age classes. The maple-beech type decreased in relative habitat value because of the extremely large increases in area (Figure 11), resulting in very low changing availability scores, which caused the habitat factor scores to be very low as well. Overall, the data show the extremely high value of forests for wildlife habitat across the state and how the value of forests for wildlife is increasing.

Geographical Patterns in Abundance of Major Vertebrates

Beginning in 1991, Illinois began an ongoing project to systematically inventory incidental wildlife observations of bow-and-arrow hunters in 10 regions of the state (see Figure 24). Although we have only one year of data, several noteworthy features have become apparent. First, on a statewide basis nothing is close to deer and squirrel in abundance (Table 10). This report is supported by estimates of densities of up to 30 deer per square mile of forested habitat (Gladfelter 1984), and a statewide population of up to 500,000 deer (C. Nixon, Illinois Natural History Survey, personal communication). In interpreting these data, however, one should bear in mind that the hunters were in search of deer and that other common forest animals, such as raccoon, are nocturnal.

The data for predators show that coyotes are the most frequently observed species and that they increase in abundance toward the southern end of Illinois (Table 10). In contrast, the number of observations of red fox was highest in the northern portion of the state (Table 10). Likewise, badger observations increased in the southern regions, while grey fox showed no strong geographical trend (Table 10). The data for game birds indicate that turkey, the most frequently observed game bird, reached peak densities along the western rim of the Illinois (Table 10). Not surprisingly, pheasant were observed most frequently in those regions dominated most strongly by agricultural lands (e.g., Grand Prairie and Central Sand Prairie) and in the northern portion of the state (Table 10). Quail showed no strong geographical trends in observation frequency.

Squirrels were observed more frequently in the southern end of the state, whereas deer and rabbit observations peaked in the northern regions (Table 10). Finally, both raccoon and housecat observations outpaced opossum and skunk observations in all regions, with no strong geographical pattern detected in any group (Table 10).

Trends in Forest Birds

In many regions of North America, forest habitat islands harbor relatively few species of forest birds. Concern is deepest for species that breed in North America and migrate to winter in Central or South America. These species are commonly called long-distance or neotropical migrants and include warblers, vireos, and tanagers.

Do islands of forest habitat in Illinois support viable populations of forest songbirds? Trends in species diversity and abundances of breeding birds within woodlots of various sizes were examined to assess this question. Long-term data are especially useful because abundances of birds and other wildlife fluctuate even under a stable habitat.

Owing to the work of the late Dr. S. Charles Kendeigh, studies of forest songbirds in the heavily farmed landscapes of east-central Illinois extend back to the late 1920s and, in some cases, continued through the mid-1970s. In 1992, birds were censused on two areas used by Kendeigh: Trelease Woods and Allerton Park (J. Brawn, Illinois Natural History Survey, unpublished data). Trelease Woods is a 24-ha woodlot surrounded by agricultural fields. The Allerton Park study plot is a 24-ha area within a 600-ha forest. Two variables are assessed in this report: numbers of species found breeding on the study areas (total and neotropical migrants) and the proportion of neotropical migrants found within the areas (relative abundances).

The number of breeding species neither increased nor decreased overall (Figure 25). Annual fluctuations were common, but for all species and for neotropical migrants, numbers of species did not decrease markedly. In fact, on Trelease Woods, numbers of species increased during the 1950s and have remained comparatively high. These data confirm numerous other studies that report higher numbers of species of neotropical migrants within larger tracts of forests than smaller tracts.

Figure 26 illustrates distinct decreases in relative abundances of neotropical migrants on both plots. Data for many more years are available for Trelease Woods, but on both plots relative abundances decreased markedly in the 1950s and remained low (importantly, abundances of two pest species, starlings [*Sturnus vulgaris*] and brown-headed cowbirds [*Molothorus*

Table 10. Numbers of various species of wildlife observed by bow-and-arrow hunters in 10 regions of Illinois.* Values represent the number of animals observed per 1000 hunter-hours.

	Region										
Species	NW Hills	NE Moraine	Missouri Border N	Grand Prairie	W Prairie	Central Sand Prairie	Missouri Border S	S Plain	Wabash Border	Shawnee Hills	Avg. for Illinois
Squirrel	824	719	864	817	892	969	1014	1141	999	1064	912
Rabbit	7	14	15	17	8	4	4	6	4	5	11
Deer	1046	992	635	895	711	792	723	791	884	887	850
Coyote	21	20	39	36	50	27	33	51	68	71	40
Red fox	15	12	16	9	8	15	13	12	10	9	11
Grey fox	1	6	2	2	2	2	4	4	5	4	3
Badger	1	0	0	0	1	1	5	1	0	5	1
Pheasant	23	26	1	22	6	21	0	0	0	0	12
Quail	3	2	45	2	50	14	15	29	4	7	15
Turkey	334	6	147	23	95	39	151	43	32	140	83
Raccoon	31	34	31	30	22	49	23	23	41	18	28
Housecat	21	31	17	16	16	13	12	20	18	14	18
Opossum	3	9	4	2	3	1	1	2	2	2	3
Skunk	1	3	1	1	1	2	2	0	0	2	1

* For a depiction of the 10 regions, see Figure 24 (below).

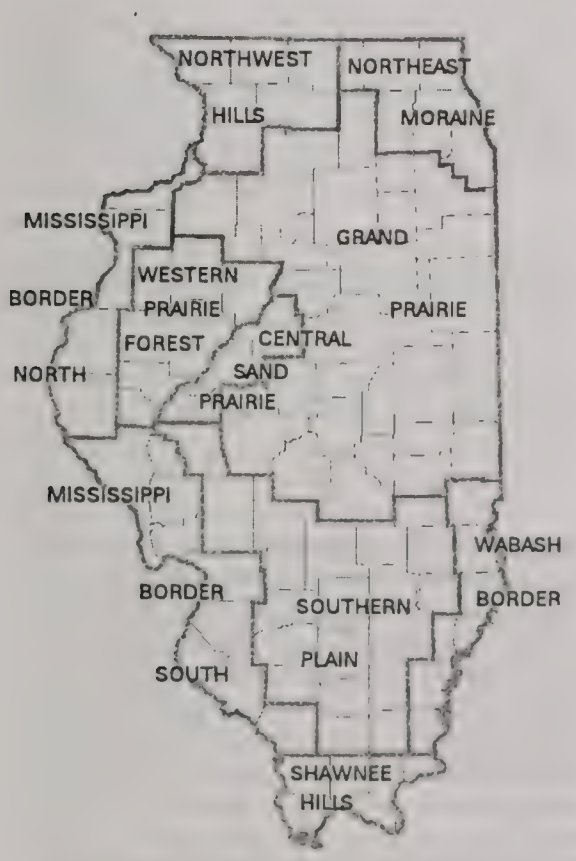


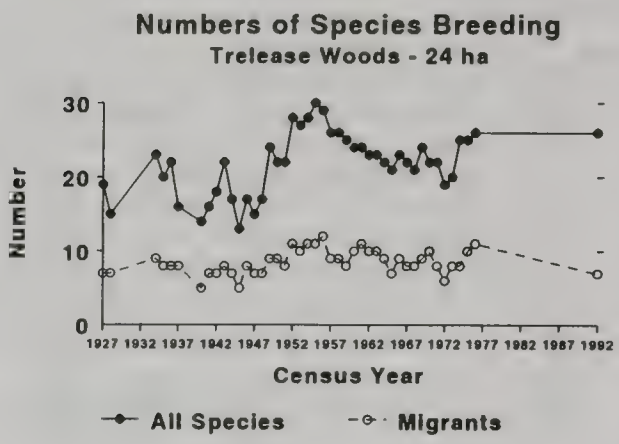
Figure 24. Illinois regions in which wildlife observations of bow-and-arrow hunters were inventoried. See Table 10 (above).

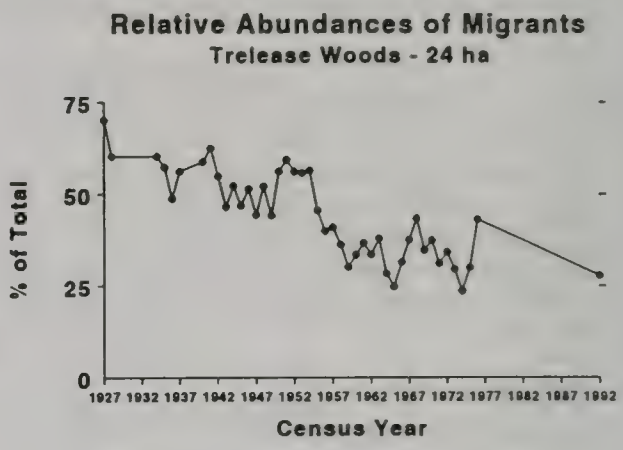
ater], were factored out of this analysis). These changes have brought about a dramatic change in the nature of breeding bird communities on the study areas and, likely, throughout Illinois. Neotropical migrants formerly accounted for over 70% of the breeding birds. Now they account for less than 50%—even on large woodlots. On small woodlots, like Trelease Woods, the problem appears extreme because the migrants account for only 25% of all resident birds.

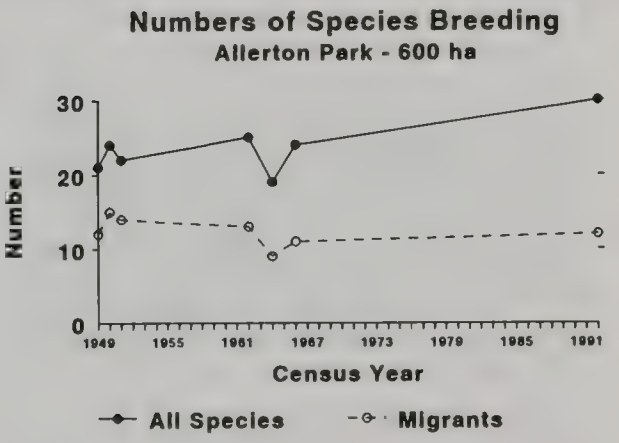
In summary the analyses indicate that few, if any, species have been lost during the 20th century, but that a large group of species may be in trouble. If trends persist, one-third to one-half the species typical of Illinois' forests may disappear from many areas.

Forest Insects

The many species of trees found in the forests of Illinois serve as food for a great diversity of insects. In more northerly regions, by contrast, the limited number of tree species supports a more limited insect fauna. With a high diversity of tree species and of insects, there appear to be more factors, such as predators and parasites, that limit the possibility of severe outbreaks of any given insect species. In contrast, agricultural crops planted as monocultures provide many examples of great buildups of an insect species that can devastate the crop. Likewise, near monocultures of spruce and fir dominate many regions of Canada and the northern states. In these areas, periodic outbreaks of the spruce budworm result in the defoliation and death of thousands of acres of forest. Although forest monocultures of pine are not uncommon in Illinois, most forests







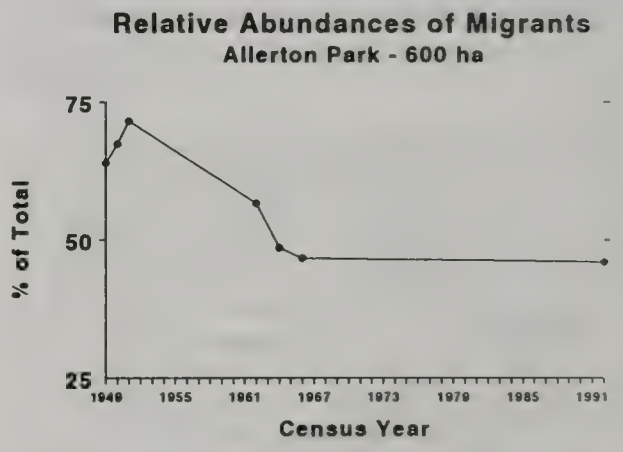


Figure 25. Number of bird species breeding in two woodland units from 1927 to 1992.

Figure 26. Relative abundance of migrant birds in two woodland study units from 1927 to 1992.

consist of mixed stands of many tree species. Thus, even though a given tree species may be seriously affected by an insect or pathogen, as in the case of Dutch elm disease, the forest is buffered from total loss.

As the Illinois landscape changed from a mixture of prairie and forest to agriculture, so too were there probable changes in the insect fauna that flourished in forests. There were no insect surveys prior to or during the earlier periods of European development, so we cannot determine what native insects may have been lost through settlement. We do know from some historical data that the original upland forests were almost exclusively mixed deciduous forest dominated by oaks and hickories. Insect species that flourish in undisturbed forests include cicadas, many species of cerambycid beetles, carpenterworms, and clearwing moths. Populations of such species probably declined as forestlands were cleared. Logged areas that were allowed to regenerate as second-growth forest supported dramatically different insect communities. Populations of native species such as the eastern tent caterpillar, fall webworm, and yellownecked caterpillar probably flourished as they do today in similar areas. The tree species diversity of the regenerated forests was not as great as it was in the former stands, and thus insect populations may have fluctuated more dramatically.

Since the 1930s there has been an increase in the number of acres of pine planted in Illinois. Insect pests native to the United States such as the northern pine weevil, pales weevil, and Nantucket pine tip moth are

now quite common throughout Illinois in areas in which they formerly did not exist because their host trees were absent.

In 1979, pine wilt disease, which is caused by a nematode that infects the native Carolina pine sawyer beetle, was discovered in Illinois. Thus, a native insect is acting as a vector for an exotic disease. The disease has devastated red and Scotch pine plantations throughout the state.

Exotic Insect Pest Introductions

With industrial development in the mid-1800s came the increased possibility of the accidental introduction of insect pests. Several important exotic insect pests of forests that are now established in Illinois include the European elm scale, the smaller European elm bark beetle, European pine shoot moth, European pine sawfly, gypsy moth, and common pine shoot beetle.

Sometime in the late 1800s the European elm scale was found in the United States. The first Illinois record is unknown, but it probably was in the early 1900s. The scale insect injures young elm trees. Heavily infested trees are stunted. In urban areas elm trees often become heavily infested, which kills some tree limbs.

In 1909, the first report of the smaller European elm bark beetle was made in Boston, Massachusetts. The first incidence of Dutch elm disease in Ohio was 1930, and in Illinois the first record was 1950. The smaller European elm bark beetle is the vector of the fungus that causes Dutch elm disease. During the 1950s through the 1970s, Dutch elm disease eliminated nearly all American elm in the forests of Illinois. In Illinois today, American elm trees exist only in limited numbers and only in communities where strict regulations dictate the rapid removal of dead trees.

The European pine shoot moth was found in Illinois in 1914. The borer infests Scotch, red, and Austrian pines. The larva bores into the new growth of pines, thereby causing a reduction in growth and disfiguration of the tree. This insect infests pines in the northern half of Illinois.

The first report of the European pine sawfly in the United States was recorded in New Jersey in 1925. The sawfly is now well established in the pine forests east of the Mississippi River, from the northern half of Illinois eastward, including southern Canada. Severe defoliation of red, Scotch, and Austrian pines occurs during population outbreaks.

The gypsy moth became established in Massachusetts in 1869 and spread westward. To date the gypsy moth has not been permanently established in Illinois; however, since 1981 male moths have been captured in pheromone traps placed in locations throughout the state. The number of male moths caught in Illinois has increased since 1986. This trend will probably continue, due to the increased mobility provided by our modern transportation system which aids in the dispersal of egg masses from infested into noninfested areas. Most of the moths have been captured in the five-county area surrounding Chicago. Once the gypsy moth becomes established in Illinois it could have a devastating effect on oak stands throughout the state. Woodlands that are already under stress are particularly susceptible to diseases after gypsy moth defoliation. For more details on gypsy moth invasion to Illinois see the chapter on agricultural lands.

If it were not for the control programs enacted by the Illinois Department of Agriculture and the USDA APHIS in the early 1980s, the gypsy moth would undoubtedly be well established in Illinois today. The number of sites with gypsy moths, however, continues to increase. Soon it may be impossible to contain the infestations. An outbreak of gypsy moths in Illinois, probably beginning in the Chicago region, seems inevitable. Infestation patterns in other states suggest that the deciduous forests of Illinois, with abundant oaks, would be severely afffected by such an outbreak. Many deciduous trees that are in a weakened condition will be killed. Understory plants that cannot tolerate direct sunlight during the period of defoliation in June will also be severely affected. The experience of eastern states suggests that forest plant communities will dramatically change as a direct result of the gypsy moth.

The most recent exotic insect introduction into Illinois is the common pine shoot beetle. The beetle was found in August of 1992 in a pine planting in Kane County. The beetle is a common forest pest in Europe, where it destroys the current year's growth of pine twigs. Beetle populations can build to large numbers in dead pine trees and pine stumps. The insect could pose a threat to certain Illinois pine plantations where dead trees are not removed and where pine stumps are not treated or removed. Quarantine regulations and control measures will soon be in effect to curtail the spread of the beetle and possibly to eliminate it from the state. Many commercial pine stands will probably be eliminated by the late 1990s because of pine wilt disease.

Under current global trade patterns, with weak restrictions on importation of plant material, exotic insect pest introductions are likely to continue. Some of these pests will become established, causing both ecological and economic effects on the forests of Illinois.

FOREST CONSERVATION

Numerous types of land are used to preserve biological diversity in Illinois forests (for example, state parks and nature preserves). One major concern for conservation of this biological diversity is undesired changes in community composition among forests through time. Early settler records suggest that most northern and central Illinois upland forests were open mature forests dominated by oaks and hickories (Anderson 1991). The abundance of oak-hickory forest was maintained through occasional fire (Anderson 1991). After European settlement, forests that were not logged began to change as a result of fire suppression. These changes continue today, as witnessed by the rapidly increasing amount of sugar maple and beech forest types within the state (Figure 11). This transition from oak-hickory forests to sugar maple forests has diminished overall forest quality by reducing species diversity (Wilhelm 1991). From an economic perspective, this shift in community composition toward sugar maple is also viewed unfavorably because sugar maple is a lower value timber product than either oaks or hickories.

With respect to other conservation efforts, recent evidence suggests that clear-cutting of forests erodes the habitat's ability to maintain populations of wildflowers (Duffy and Meier 1992). Clear-cutting causes severe damage to the understory herb layer, and it appears that this herbaceous flora does not recover during a typical growth cycle between cutting events. A recent trend that has ameliorated this effect is that the managers of Shawnee National Forest are now moving away from the use of clear-cutting in sites that support native forest species.

Forest size is an important predictor of habitat quality. Of the 214 grade A and B forest sites classified by the Illinois Natural Areas Inventory (White 1978), only 11% are greater than 100 acres (Figure 27). By contrast, among all forest parcels in Illinois, 55.7% are greater than 100 acres (Figure 28), indicating that our large forest patches are less frequently of high quality than we would expect. This is likely to be the result of large tracts being used for intensive logging. At the same time, 19% of sites classified as grade A or B forest are so small (less than 10 acres) that they may experience severe problems maintaining biological diversity (Figure 27). Even the majority of the grade A and B forest sites (20–50 acres, Figure 27) are prone to edge and small patch size effects. To put this in perspective, if a 40-acre site were square, there would be no place in this forest more than 220 yards from an edge. Given that most forest patches are linear strips along waterways, most high quality forest is within 100–200 yards of a habitat border (see subsequent section in this report on forest fragmentation). Finally, the data on grade A and B sites show that there are very few sites supporting flatwood or sand forest vegetation, making them critically threatened habitats (Figure 27).

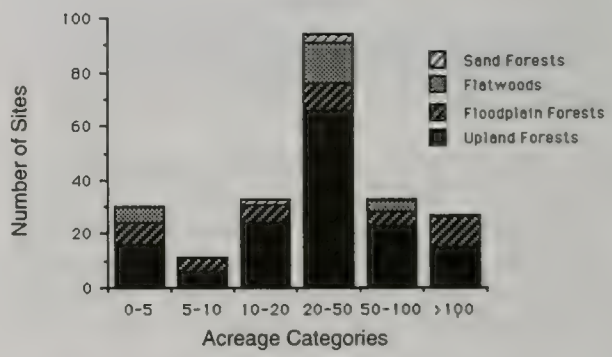


Figure 27. Size distribution of grade A and B forest parcels identified by the Illinois Natural Areas Inventory (White 1978) for each of four forest types.

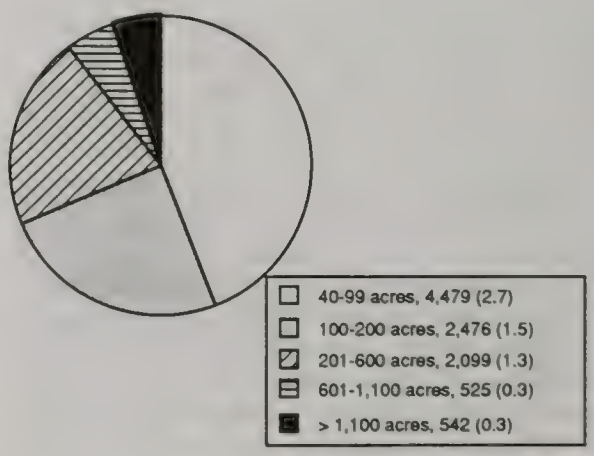


Figure 28. Number of forested parcels in Illinois by size and average number of parcels per township equivalent (36 square miles). The total number of parcels of a given size is the number immediately following the size; the average number of parcels of a given size per township is given in parentheses. Source: U.S. Geological Survey land-use data, 1973–1981.

STRESSORS

Pollution

Ozone, NO_2, and SO_2 are among the numerous anthropogenic pollutants that pose well-documented threats to forested habitats (see Schulze et al. 1989, Johnson and Lindberg 1992, Eagar and Adams 1992). Case studies demonstrate the severe effects of pollutants on ecosystem function in forested habitats (e.g., Johnson and Lindberg 1992). Further, widespread pollutants have been implicated in forest declines (e.g., Schulze et al. 1989, Eagar and Adams 1992). In particular, pollutants increase levels of stress in trees (Johnson and Fernandez 1992, McLaughlin and Kohut 1992). Stress increases the susceptibility of trees to other sources of mortality such as plant pathogens (Schoeneweiss 1975, 1978; Manion 1981). Studies of the abiotic environment suggest that Illinois does not, as of yet, suffer from the same levels of acid rain that have been implicated in the decline of forests in the northeastern United States or northern Europe. The pollutant deposition data are supported by recent data indicating lower overall forest damage in Illinois than other regions of the eastern United States (Table 3).

Deforestation

A recent study comparing plant composition in Appalachian old-growth and second-growth forests showed that herbaceous species diversity does not recover following clear-cutting, not even after 80 years (Duffy and Meier 1992). Similarly, the long-term effect of past clear-cutting in Illinois may have been to reduce the biodiversity of Illinois forests. Illinois forests are going through a process of maturation (Figure 13), and these younger stands may require specific management to recover natural levels of biodiversity. We need additional research to assess the potential damage in Illinois, as well as management programs to restore woodland habitats. Fortunately, most current forestry operations in Illinois employ less destructive selective logging techniques to harvest timber. Nonetheless, we need additional reserach on the long-term impact of selective logging on forest biodiversity.

Fragmentation

The Illinois forested landscape, as discussed above, is extremely fragmented. According to U.S. Geological Survey data, there were 10,121 forested parcels of 40 acres or more in Illinois in 1980. These parcels averaged 358 acres, and about 44% of the parcels were 100 acres or less (Figure 28). There were an average of 6.1 parcels per township (an area of 36 square miles). Of course, the density of forest patches was much higher in the southern counties.

Fragmentation of forest habitat has negative implications for biological diversity at many levels. First, many plants and animals may need large blocks of uninterrupted forest for successful reproduction (e.g., see Robinson 1988, Blake 1991). Several studies have found that small habitat patches tend to be dominated by generalist birds, and as habitat size increases, the diversity of birds requiring specialized habitats also increases (Martin 1981, Whitcomb et al. 1981, Ambuel and Temple 1983, Blake and Karr 1987). In an examination of forest patch use in Illinois by migrant and resident birds in 1979 and 1980, Blake (1991) found that there is a high level of predictability of habitat patch use based on the size of the patch. In studying habitat use on 12 forest remnants that varied from 1.8 to 600 hectares, Blake found that small patches (< 20 hectares) were dominated by generalist birds.

Second, as large tracts of forest area are broken into small, isolated woodlots, more forest edge is created and more opportunities exist for edge-adapted species to usurp habitat from forest-interior species. In a study of old-growth forest fragments in Indiana, Brothers and Spingarn (1992) found that 21 species of alien plants had invaded the forests. While the number of species (species richness) of the alien flora invading the forest fragments dropped dramatically just 2 m inside the forest edge (compared to 2 m outside the forest edge—Figure 29), the frequency of alien species (compared to native species) remained above 20% over 20 m into the forest in many instances (Figure 29). Further, the frequency of alien species was higher on south-facing edges than on north-facing edges. These results suggest that an important aspect to consider in forest fragments is the edge-to-center ratio (or perimeter-to-area ratio) of individual fragments. Increasing edges of fragments increases the probability of invasion by species from other habitats. In Illinois, much of our remaining forests occurs as one of two types: (1) very small, isolated patches where the edge-to-center ratio is very high and (2) riparian zone forests where there is practically no center and lots of edge. Both of these forest fragment types are very susceptible to the negative effect of habitat edges.

The conclusion that habitat edges should be minimized runs counter to traditional wildlife management goals to establish habitat edges to enhance populations of deer, pheasant, and other species valued primarily by hunters. Although it is difficult to estimate

presettlement deer populations, we know that populations increased in the 1800s in association with land clearing (Torgerson and Porath 1984). During the early 20th century, deer populations were very low but have rebounded substantially during the past 30 years (Gladfelter 1984, Torgerson and Porath 1984). This increase is, in part, a result of managing forestlands for habitat openings and food plots (Gladfelter 1984). Although the current abundant deer populations are viewed favorably by hunters, they appear to pose serious threats to biological diversity in forests (Anderson and Loucks 1979, Alverson et al. 1988, Strole and Anderson 1992, Anderson and Katz 1993). This conflict between the conservation of plant diversity and deer points out an inherent problem with managing biological resources: species-based management goals often conflict with those developed to maintain the full array of native biodiversity.

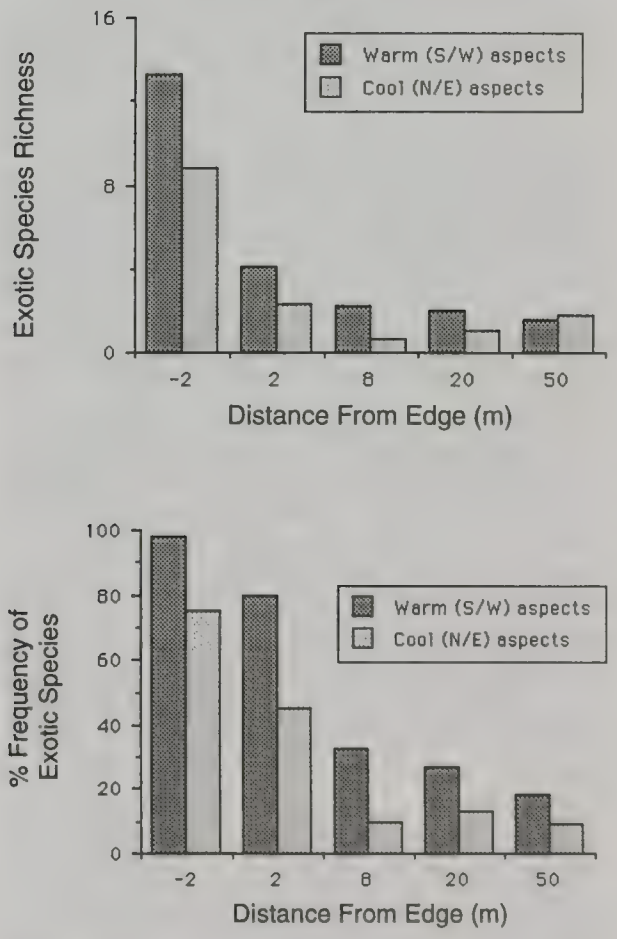


Figure 29. Mean alien species richness (top) and mean frequency of sample transect segments containing alien species (bottom), summarized by transect position and aspect. Sample size = 7 for each combination of transect and aspect. Redrawn from Brothers and Spingarn (1992).

Third, fragmentation of forests into small habitat islands results in small effective population sizes. Population size is the best predictor of extinction probability. Population Viability Analysis (PVA) is a tool used to predict the likelihood that a population will persist through time (Gilpin and Soule 1986). Recent reviews of PVA (Soule 1987; Shaffer 1981, 1987; Menges 1992) conclude that, in general, effects attributable to environmental stochasticity are most likely to cause population extinction. Further, populations of fewer than 200 individuals are moderately susceptible to extinction through environmental stochasticity (Menges 1992). Because most Illinois forests are very small, many species may be restricted to small populations. Thus, fragmentation may increase the propensity for small, isolated populations to become locally extirpated.

Finally, the disjunction of forest patches may inhibit movement of individuals—particularly, several species of plants, insects, and small mammals—between isolated habitats. This spatial isolation may, in turn, result in genetic isolation. Genetic isolation can be detrimental to the long-term health of resident populations because it increases inbreeding, which can lead to an erosion of the genetic variability and, eventually, of the viability of these populations (see discussion in prairie chapter on genetic concerns). Inbreeding depression is likely to become a problem over the short term for certain types of organisms. Organisms that disperse well— such as birds, large mammals, trees, and many robust insects—are likely to maintain substantial gene flow despite habitat fragmentation. For organisms that live very long—such as trees, some shrubs, perennial herbs, and fungi—any increase in inbreeding is likely to take a very long time to erode local variability to the point where populations may become inviable. In contrast, organisms that do not disperse well and have short generation times (e.g., small mammals, sedentary insects, and short-lived herbs) may show severe inbreeding problems over the course of a few generations (Barrett and Kohn 1991). There is little direct evidence with which to gauge the magnitude of inbreeding depression effects in Illinois at the present time.

Global Climate Change and Carbon Dioxide Sequestration

Because Illinois has undergone massive changes in total forest volume over the past several decades, the amount of carbon being sequestered into Illinois forest biomass has likewise changed considerably. From 1948 to 1962, there was a slight loss of total forest volume due to conversion of forestland to other uses (Figures 16, 30). This loss was compensated by the harvesting of wood products, which put 0.29 million metric tons of carbon into long-term storage. The result was that forestlands were a net sink of 0.2 million metric tons of carbon per year during 1948–1962. After 1962, there was a gain in forestland and especially a gain in forest volume per unit of forestland; in addition, carbon sequestration into long-term storage of wood products increased slightly. The net result was carbon sequestration of about 1.37 million metric tons of carbon per year from 1962 to 1985 (Figure 30). Even though the amount of carbon sequestered by Illinois forests has increased, however, this amount still represents only about 2.7% of the total carbon emissions that the people of Illinois contribute to the atmosphere each year.

Ecological Response to Global Climate Change

Predictions of global warming suggest, barring extreme global restrictions on the use of fossil fuels, that atmospheric CO_2 levels will double during the next century. This doubling of CO_2 is predicted to result in a global increase in temperature of between 1.5°C and 4.5°C (Houghton et al. 1990). Average increases are expected to be from 0.2°C to 0.3°C per decade (Houghton et al. 1990). Temperature changes will not be evenly distributed around the globe, with the greatest temperature changes at high latitudes, and particularly during the winter months (Houghton et al. 1990). In addition, mid-continental regions should, in general, experience a decrease in growing season precipitation and an increase in the frequency of drought events. However, the predictions with respect to precipitation are much less firm than those for temperature.

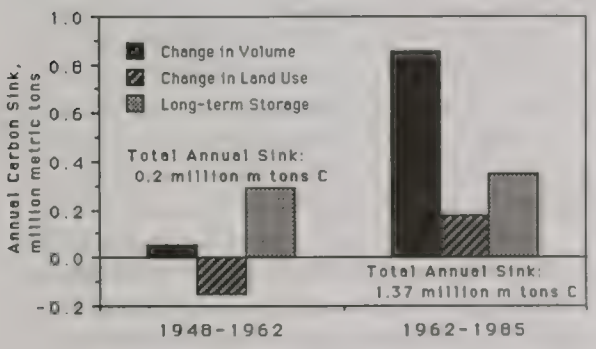


Figure 30. Carbon sinks and sources related to Illinois forestlands, 1948–1985. Depicted are amounts of carbon sequstration due to changes in the volume of trees per unit of forest area, changes in land use, and changes in the long-term storage of carbon as a result of the harvesting of timber products.

These climate changes may have several biological ramifications. First, warmer winter temperatures are likely to result in increased survivorship of over-wintering insects. This may pose problems with respect to both pests of forests and crop plants, some of which now over-winter south of Illinois. Second, increased drought frequency may result in increased frequencies of plant disease (Schoeneweiss 1975, 1978; Manion 1981). Given that the major identifiable sources of mortality in trees are insects and disease (Table 1), climate change is likely to exacerbate existing problems. In addition, climatic warming may result in earlier spring greening of vegetation (M.D. Schwartz 1990, 1992), enhanced net growth rates (Melillo et al. 1990), increased levels of herbivory (Melillo et al. 1990), and shifts in the competitive interactions among species (Melillo et al. 1990). All of these indirect effects are likely to alter the ability of Illinois forests to support timber production in, as yet, unpredictable ways.

The primary realm of uncertainty in these predictions of changes due to increases in temperature relates to the numerous direct effects of atmospheric CO_2 on plants (for reviews, see Melillo et al. 1990, M.W. Schwartz 1992). For example, an increase in atmospheric CO_2 levels: (a) decreases water stress (Farquhar and Sharkey 1982), (b) increases plant growth rates (Bazzaz and Carlson 1984, Idso et al. 1987), (c) alters nutrient uptake rates (Luxmoore et al. 1986), (d) alters phenology (Long and Hutchin 1991), and (e) changes plant tissue chemistry and subsequent rates of herbivory (Lincoln and Couvet 1989). Most of the changes in direct response of plants to increases in CO_2 levels will ameliorate the effects of climate change. We remain far from being able to predict these responses with any certainty.

Situated at the edges of southern and northern forests, and along the eastern edge of the prairie, Illinois is in a position—if climatic warming occurs as predicted—to lose many plant species from northern counties while

acquiring new species in southern counties as range limits shift northward (Davis 1989). While the retraction of southern range boundaries may be rapid in response to climate change, the movement of northern edges of distributions is likely to be quite slow (M.W. Schwartz 1992, 1993). Thus, if warming proceeds as climate change models predict, Illinois may experience a net decrease in natural biological diversity.

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AGRICULTURAL LANDS

SUMMARY

The nature of agriculture and the impact of farming on environmental conditions in Illinois are closely tied to trends in cropping systems, livestock production, soils, and the chemical and mechanical inputs used to produce farm products.

Crop rotations that traditionally included soil-building forage legumes and small grains have diminished as the production of corn and soybeans (row crops) has increased—a trend that has been particularly important since the early 1960s. The expanded production of row crops and emerging farm technologies have led to increasing crop production per unit of land and more farmland planted in crops. Technological advances affecting yields include improved plant hybrids, inorganic fertilizers, and a plethora of pesticide compounds.

Chemical and mechanical disturbances (inputs) are fundamentally important to describing environmental trends because they constitute the primary disturbances on farmland. Important mechanical disturbances include the types of farm machinery and agronomic practices used for crop planting, cultivation, and harvest.

Because agriculture in Illinois is characterized by chemical- and mechanical-intensive technologies, four major issues are typically discussed at the state level regarding agriculture and the environment. These include (1) soil conservation, erosion, and the accelerated sedimentation of rivers and lakes; (2) use of nitrogen fertilizer on cropland and increasing contamination of water supplies by nitrates and other fertilizer compounds; (3) extensive pesticide use and the contamination of water supplies with pesticide residues, which may affect human health and wildlife; and (4) the impact of farming on biodiversity and wildlife on farmland.

There has been progress in soil conservation, but achieving soil and water quality goals in Illinois remains a foremost challenge for agriculture. Likewise, integrated pest management has been successful in using host plant resistance and biological control to suppress agricultural pests, but chemical control is still a widely used option for economic reasons in agriculture and for public health reasons in mosquito control.

The decline in the abundance of upland game species since the 1960s is a case study of how intensive agriculture has negatively affected habitat for many wildlife species traditionally common to the farm landscapes of Illinois. The decline in upland game populations and other farmland wildlife is due to expanded row crop production and the loss of small grains and perennial vegetation including hay and the loss of uncropped farmland such as wetlands, savannas, and permanent pasture.

INTRODUCTION

Farms dominate the landscape of Illinois. In fact, over 80% of the 35.7 million acres of Illinois land is currently in farms. Most of the farmland is planted in row crops, some is planted with perennial hay or orchard crops, and a small fraction is pasture and woodland. Approximately two-thirds of the farmland, and therefore half of Illinois, is planted in the primary row crops, corn and soybeans.

Clearly, an assessment of critical environmental trends must consider the impact agricultural practices and farmland have on the state. In addition, the activities of industries and cities will influence plants and animals that inhabit farmland. This second perspective is necessary because cropland, pasture, and woodlands on farms create a diverse landscape ranging from field to orchard, from windrow to pasture, and from windbreak to woodland. The diversity and abundance of plant and animal species may be lower per acre on agricultural land than on other types of land, but the large amount of farmland in Illinois means that agricultural lands provide many resources for wild and managed animals and plants.

Typically, four major concerns are discussed at the state level about agriculture and the environment. The first involves soil conservation, erosion, and the sedimentation of rivers and lakes. Illinois has the world's best soils for crop production. These soils were created by the plants and small animals living in the wetlands, prairies, and forests that existed in Illinois before humans cultivated the land.

Second, the use of nitrogen fertilizers, crop yields, and nitrate contamination of water supplies have all

increased since 1940. Efforts are being made to optimize, and often reduce, total nitrogen applications to cropland to maintain yields of corn while protecting groundwater and surface water.

Third, pesticide use and residues in water supplies are a major concern because of possible effects on human health and wildlife. The most common herbicides are being found in groundwater samples taken from wells across the state. Insecticides may harm birds, mammals, bees, or fish depending on the type of chemical and its concentration. For the past 20 years, integrated pest management has attempted to optimize—and where possible, reduce—chemical pesticide use while decreasing damage by pests. Nevertheless, insect, weed, and fungus abundance and pressure on crops from these pests have not declined over the past decades.

The fourth important concern is biodiversity and wildlife on farmland. Some wild plants and animals inhabit the margins between wild and managed areas or inhabit managed woodlands on farms. Often cropland or pastures provide part of the resources necessary for the survival of wildlife populations. This is especially true in regions of the state without large natural areas.

This chapter describes farm production trends and key environmental factors such as vulnerability of soils to erosion, agrichemical use, crop pests, and wildlife. In addition, other data are described that may help us manage agricultural and neighboring lands to deal with the four major concerns described previously.

CRITICAL INDICATORS OF AGRICULTURAL LAND CONDITIONS

The nature of agriculture and the impact of farming on environmental conditions of Illinois are closely tied to trends in cropping systems, livestock production, soils, and the chemical and mechanical inputs used to produce farm products.

Chemical and mechanical disturbances (inputs) are fundamentally important to describing environmental trends because they constitute the primary disturbances on farmland. Key chemical inputs include the use of inorganic fertilizers, insecticides, and herbicides. Natural and anthropomorphic forces move these chemical compounds through the atmosphere and through other terrestrial and aquatic environments. In fact, farm chemicals are a major source of nonpoint-source pollution in Illinois. The status of major agricultural pests is also an important consideration because chemical, biological, and mechanical controls of pests bear upon environmental quality.

Important mechanical disturbances include the farm machinery and agronomic practices used for crop planting, cultivation, and harvest. Mechanical disturbances, in conjunction with soil properties and chemical inputs, affect soil and water quality; that is, they affect the extent to which runoff and leaching of chemicals are significant nonpoint sources of pollution.

For over 150 years agriculture has been the most important determinant of biodiversity in Illinois. Trends in biodiversity, the numbers of endemic plant and animal species present, indicate the extent to which fundamental ecosystem processes have been altered by humans and, in a broader sense, indicate the health of the environment. In addition to biodiversity, the abundance of key wildlife species traditionally common to Midwestern farm landscapes is a measure of how suitable agricultural lands are for important game species.

Trends in Agricultural Land, Products, and Tillage

Farmland consists of cropland, pasture, and woodlands on farms. Figure 1 shows that while the amount of farmland has decreased approximately 10% since 1950, the average size of an Illinois farm has more than doubled during the same period. Figure 2 shows how average farm size has changed in Illinois counties since 1964. Since the 1960s, the number of acres of cropland has declined in urban and heavily forested counties (Figure 3). In general each unit of cropland has become more productive. Corn yield and the All Crop Production Index (CPI) calculated by the Illinois Department of Agriculture have increased over the past 40 years in Illinois, primarily because of increased inputs of synthetic fertilizers and pesticides (Figure 4).

Since 1945 a variety of federal farm programs have resulted in the diversion of cropland from crop production to other uses, including fallow, for short or long periods of time (Figures 5 and 6). Cropland diverted from production has been relatively common in the 1980s throughout the state. Diverted cropland is important (when managed appropriately) for protecting soils. Cropland diverted from production under long-term contract (such as the Conservation Reserve Program) is typically established in perennial grasses and other vegetation valuable for building and protecting soil. However, the extent to which land diverted

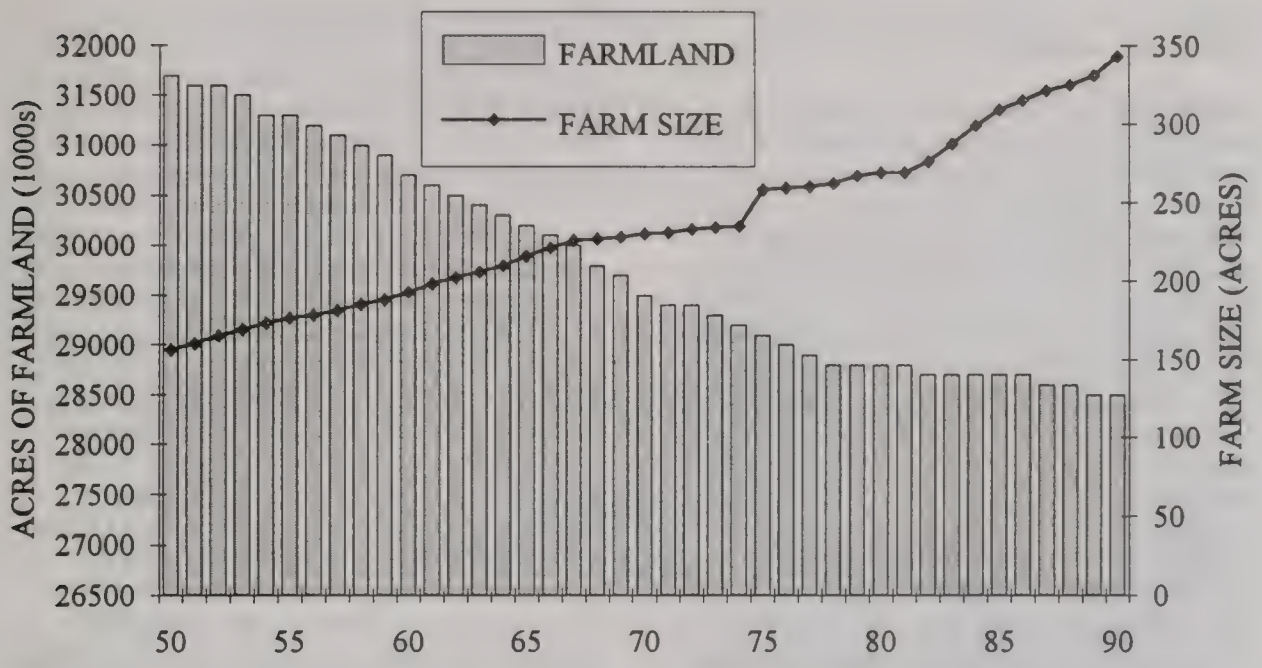

Figure 1. Amount of farmland and average farm size in Illinois in recent decades. Source: Illinois Department of Agriculture.

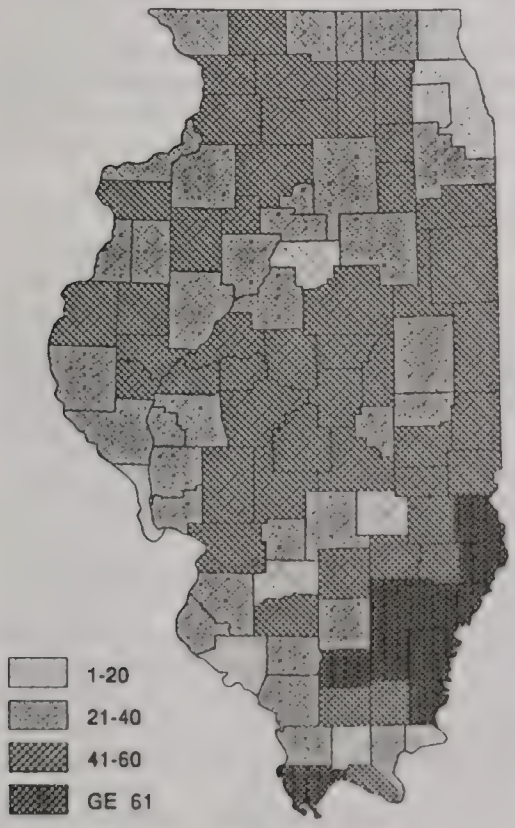

Figure 2. Percent increase in acres per farm in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

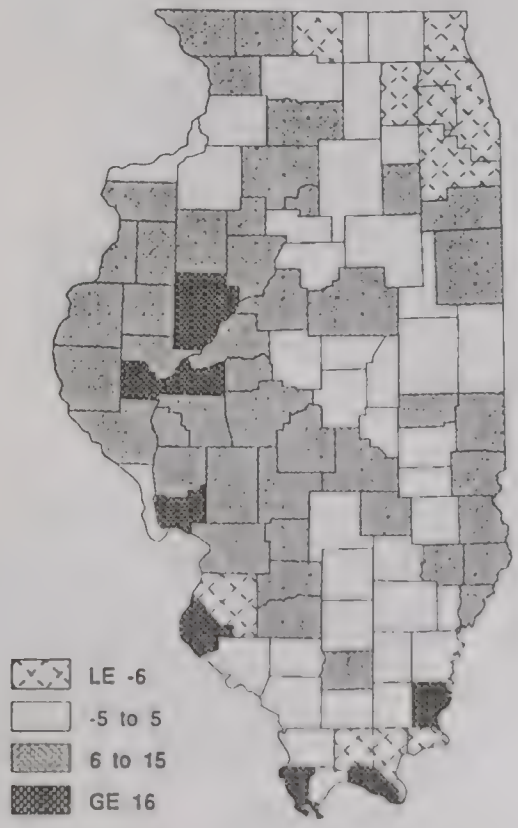

Figure 3. Percent change in acres of cropland in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

from production under annual contract has achieved soil and water quality goals has not been monitored.

Since World War II agriculture has moved from relatively small, diversified farming systems to large, highly specialized cash grain units. As cropping systems have changed in recent decades, key animal, mechanical, and chemical disturbances have also changed. Crop rotations that traditionally included soil-building forage legumes and small grains have diminished (Figure 7) as the production of corn and soybeans (row crops) has increased—a trend that has been particularly important since the early 1960s (Figure 8). Since 1964, the amount of land planted in soybeans has increased dramatically in most counties (Figure 9), while the changes in corn acreage have been more varied (Figure 10). Rotation of corn and soybeans every other year is good for pest management, but soybean production can increase soil erosion. Comparing county-level trends from 1964 to 1987 shows that production of oats has generally increased, especially in the southern half of Illinois (Figure 11), while production of hay has generally declined (Figure 12). However, oat plantings in 1987 were unusually high because 30% of the corn base was diverted from crop production that year—most of which was planted to oats. Wheat production was lower in 1987 than in 1964 except in the extreme northwest and south (Figure 13).

Because of this expansion of soybean and corn production, mechanical disturbances of the soil have greatly increased since World War II. Fall tillage (using primarily the moldboard plow) increased from the early 1950s through the late 1970s (Figure 14). Conservation tillage, which is defined as at least 30% of the soil surface protected by crop stubble after spring planting, has increased sharply during the 1980s with the adoption of no-till planting systems and other tillage implements that reduce soil disturbance (Figures 15 and 16). Although Illinois has led the nation in the adoption of conservation tillage during much of the 1980s, an extensive amount of cropland with highly erodible soils remains susceptible to erosion (Figure 17). There has been progress in soil conservation, but achieving soil and water quality goals in Illinois remains a foremost challenge for agriculture.

Areas producing fruits and vegetables tend to receive extensive amounts of commercial fertilizers and pesticides to control plant diseases, insects, and weeds. Therefore, trends in orchard and vegetable production are important from an environmental standpoint. Although orchard and truck gardens are significant to local economies, the production of fruits and vegetables is declining. In 1991, snap beans, asparagus, and sweet corn were produced on about 29,000 acres, down from about 43,000 acres in 1984. The production

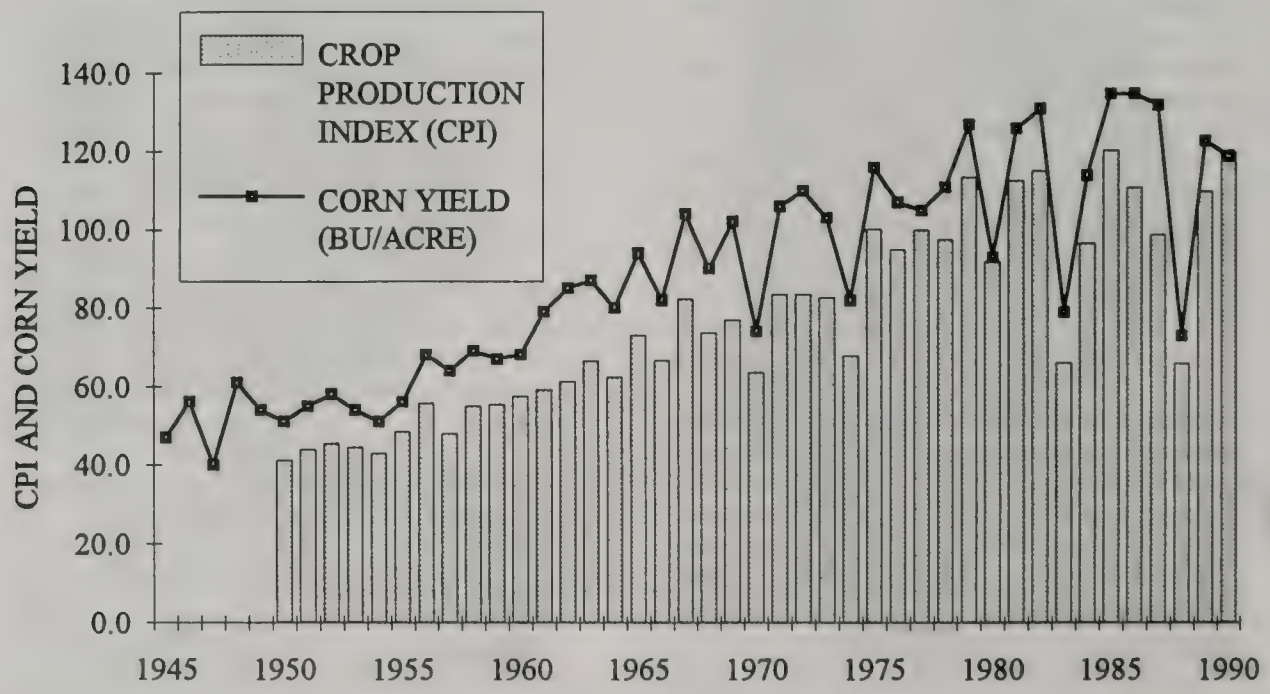

Figure 4. Crop production index and corn yields in Illinois in recent decades. Source: Illinois Department of Agriculture.

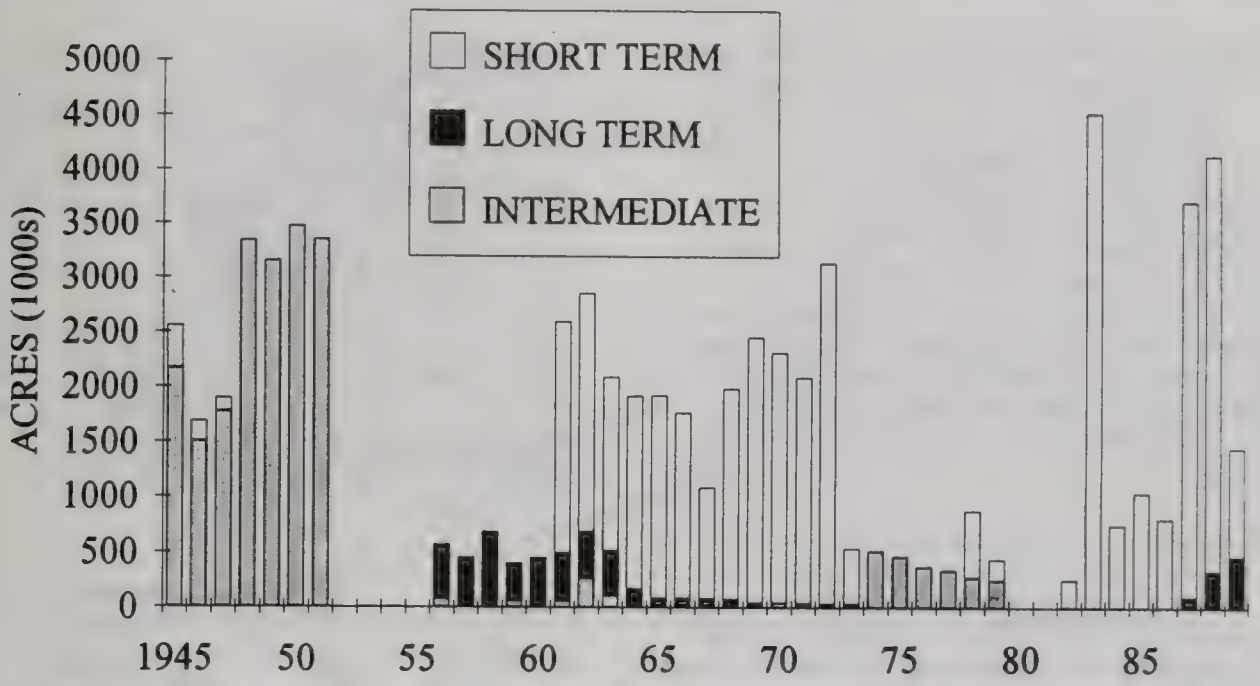

Figure 5. Amount of cropland diverted from production by various farm programs in recent decades in Illinois. Values are given for long-term (>5 years), intermediate (3–5 years), and short-term (1–2 years) contracts. Source: Illinois Department of Agriculture.

of fruit (primarily peaches and apples) has also declined moderately during the 1980s (data for fruit and vegetable production from the U.S. Department of Commerce, Bureau of the Census).

Although 50% of the state's land is used to produce corn and soybeans, which are primarily used for livestock feed, the number of cattle and hogs has declined over the past 30 years (Figures 18–20). These trends have been followed by decreases in the amount of farmland and woodland grazed (Figures 21 and 22). Livestock production is highest in western and northwestern counties.

Trends in Pesticide Use

Chemical pollution on farmland results from applications of pesticides (primarily herbicides and insecticides). Unlike a point-specific source of pollution, such as an industrial smokestack, agricultural pollution originates over multiple fields and farms when agrichemicals and topsoil move off the site of application through air and water. Such nonpoint-source pollution has become a serious problem over the past few decades—both on farmland and in other terrestrial and aquatic environments.

Use of such chemical compounds has increased dramatically since World War II. However, the active

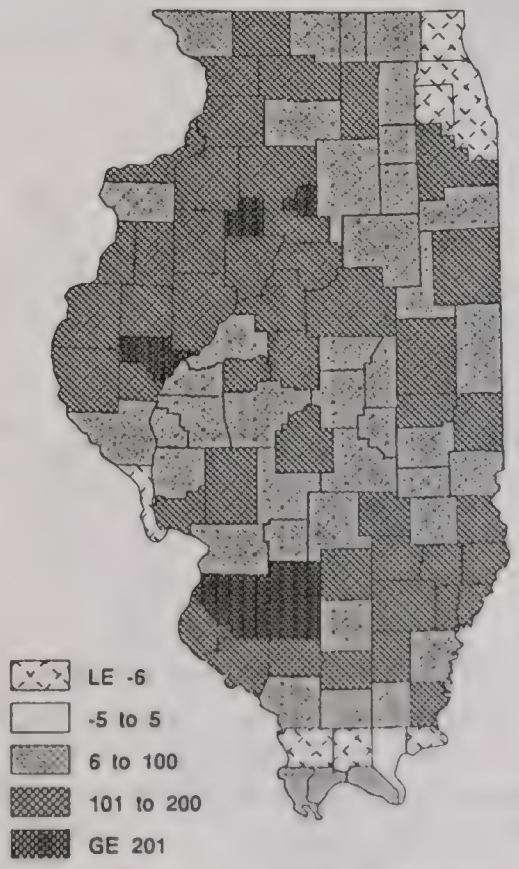

Figure 6. Percent change in amount of farmland diverted from crops in Illinois counties, 1964 to 1987. Sources: U.S. Department of Commerce, Bureau of the Census; U.S. Department of Agriculture, Soil Conservation Service; Illinois Department of Agriculture.

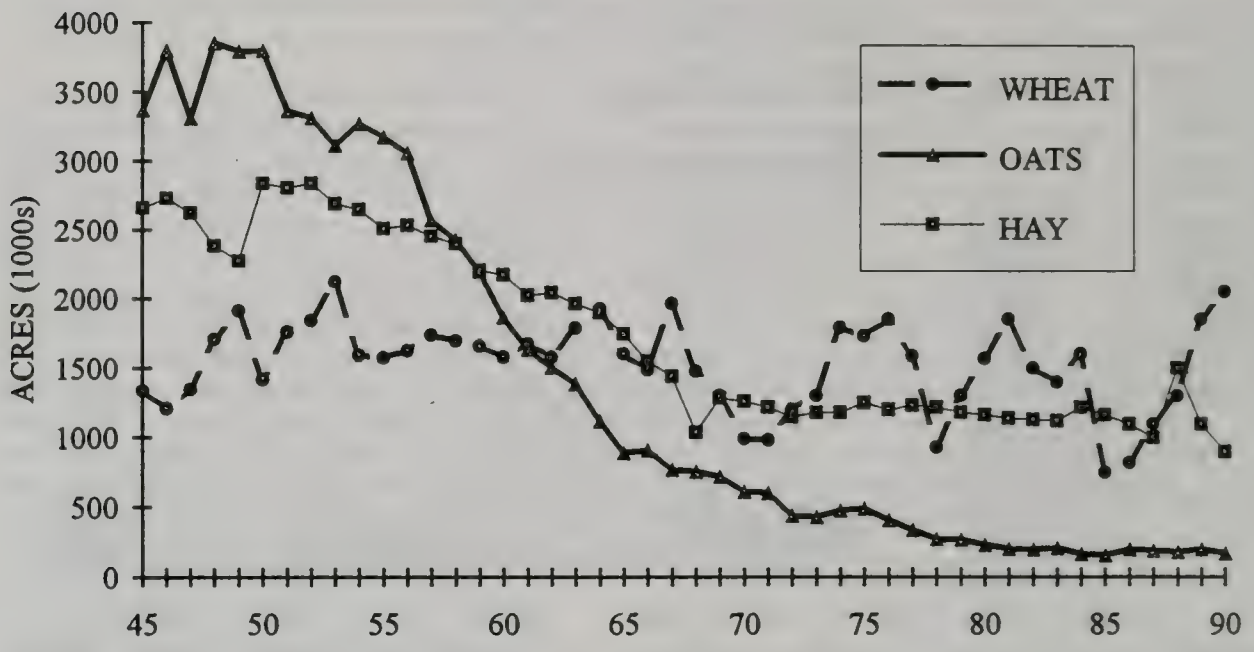

Figure 7. Number of acres planted in wheat, oats, and hay in Illinois in recent years. Source: Illinois Department of Agriculture.

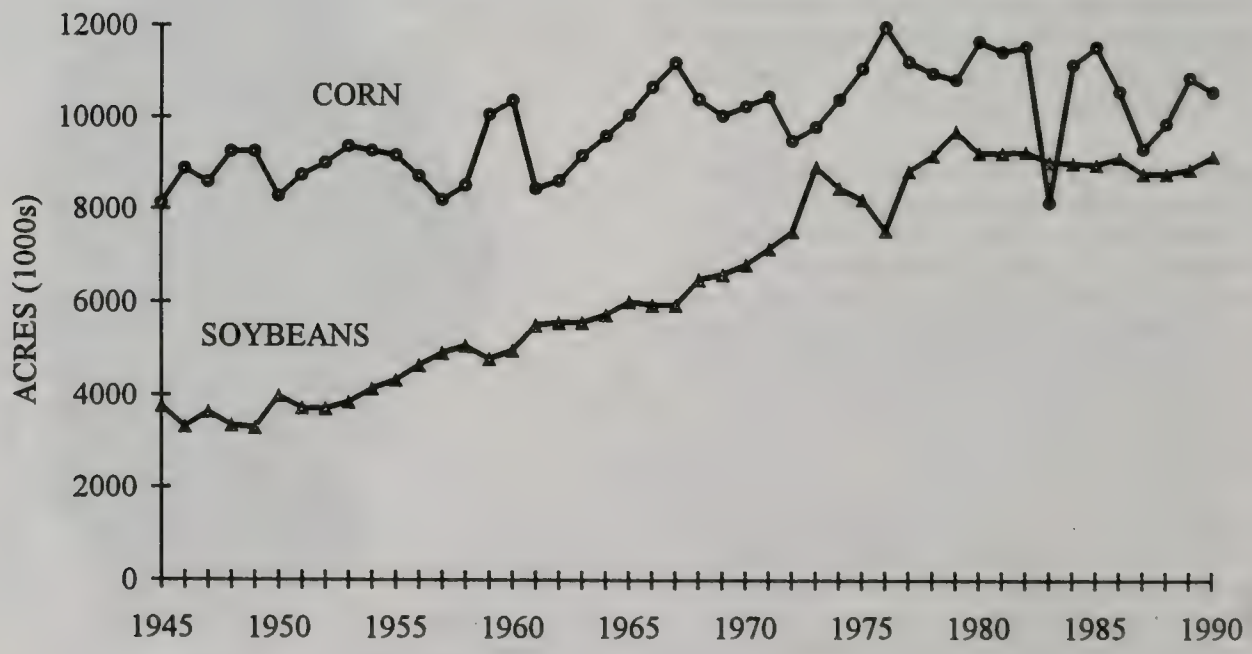

Figure 8. Number of acres planted in corn and soybeans in Illinois, 1945–1990. Source: Illinois Department of Agriculture.

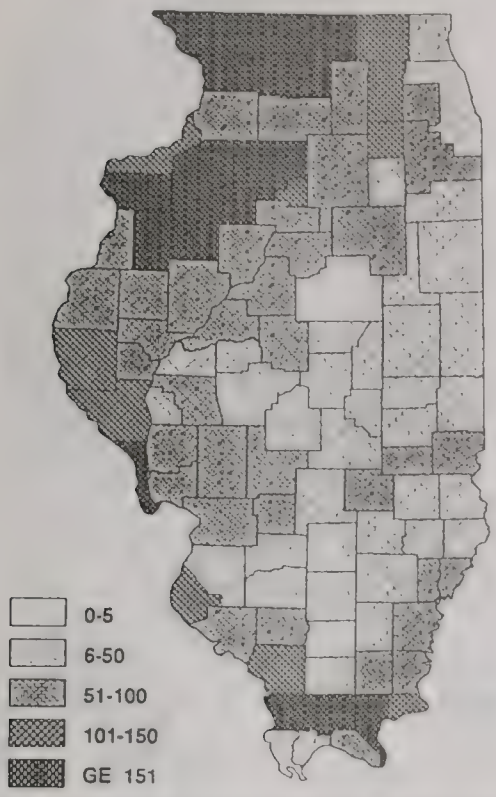

Figure 9. Percent increase in acres of soybeans in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

ingredients in herbicides and insecticides have changed over time. Insecticides that are widely used today tend to be acutely toxic to nontarget invertebrates and vertebrates for a few days, with toxicity declining sharply thereafter. This limited time window for acute toxicity is a major improvement compared to insecticides such as DDT and other chlorinated hydrocarbons that were once widely used. Compounds such as DDT, and their metabolites, persisted for decades; they pervaded the ecosystems of Illinois and were magnified in natural food chains. The demise of populations of top predators such as the bald eagle was directly related to such chemical compounds used extensively in agriculture.

Because field corn has several serious weeds and insect pests (e.g., corn rootworm) and because corn occupies so much of Illinois cropland, it receives the greatest amount of pesticides compared to other crops. However, on a per acre basis, fruit and vegetable crops typically are treated with much greater amounts of pesticides than corn. Figure 23 presents the estimated trends in corn pesticide use since 1945 from a variety of U.S. government sources of information. Herbicide use in corn has increased dramatically since 1964

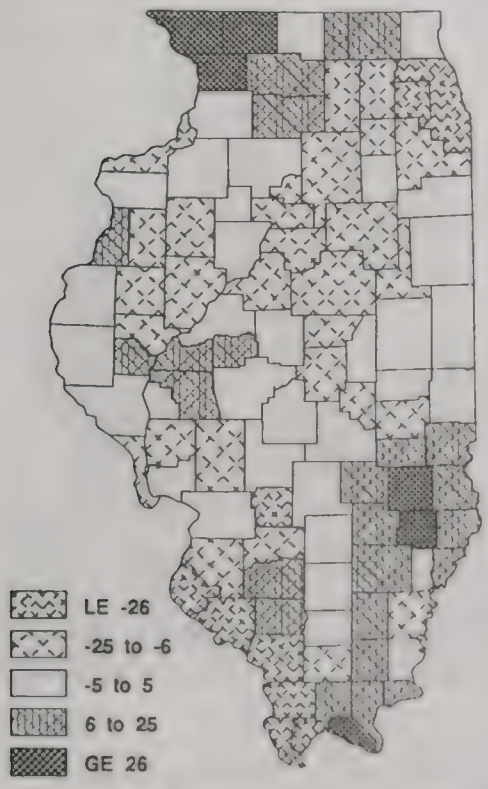

Figure 10. Percent change in acres of corn in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

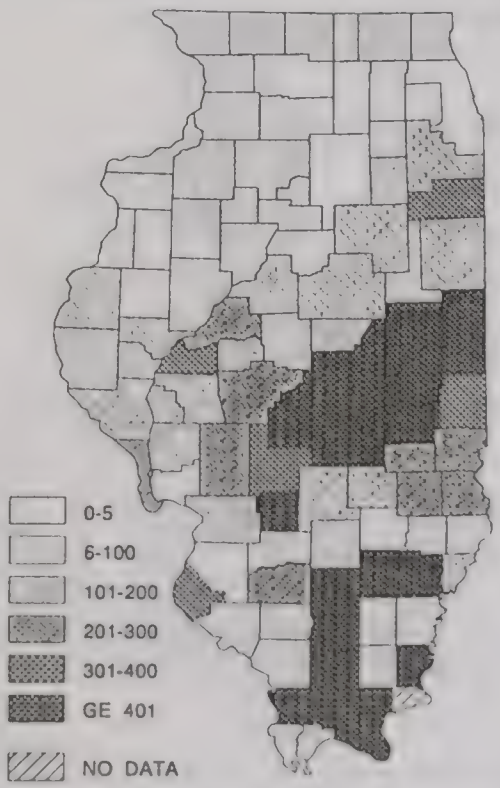

Figure 11. Percent change in acres of oats in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

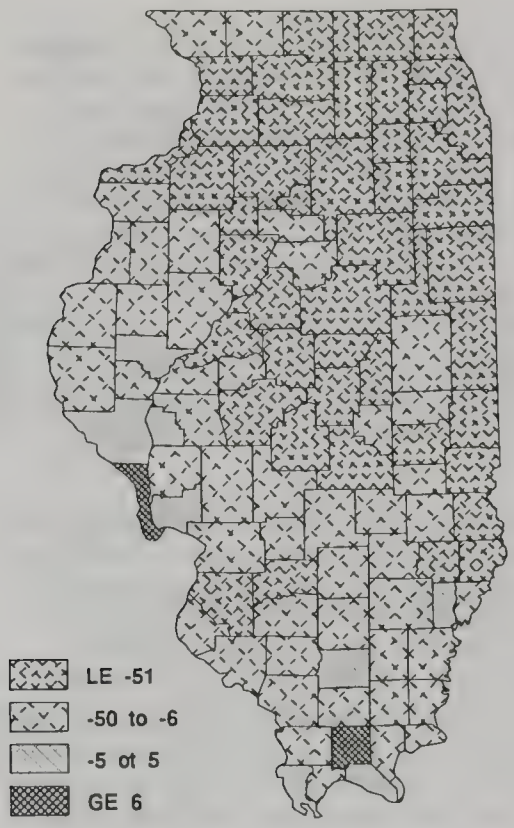

Figure 12. Percent change in acres of hay in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

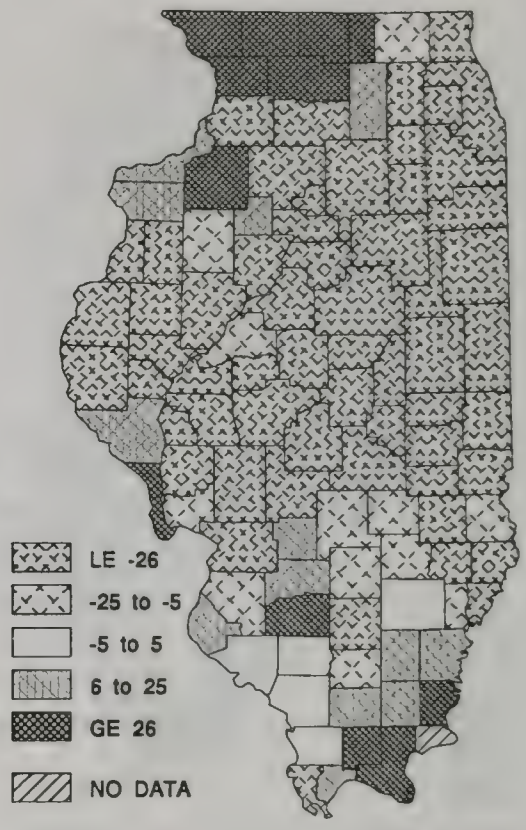

Figure 13. Percent change in acres of wheat in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

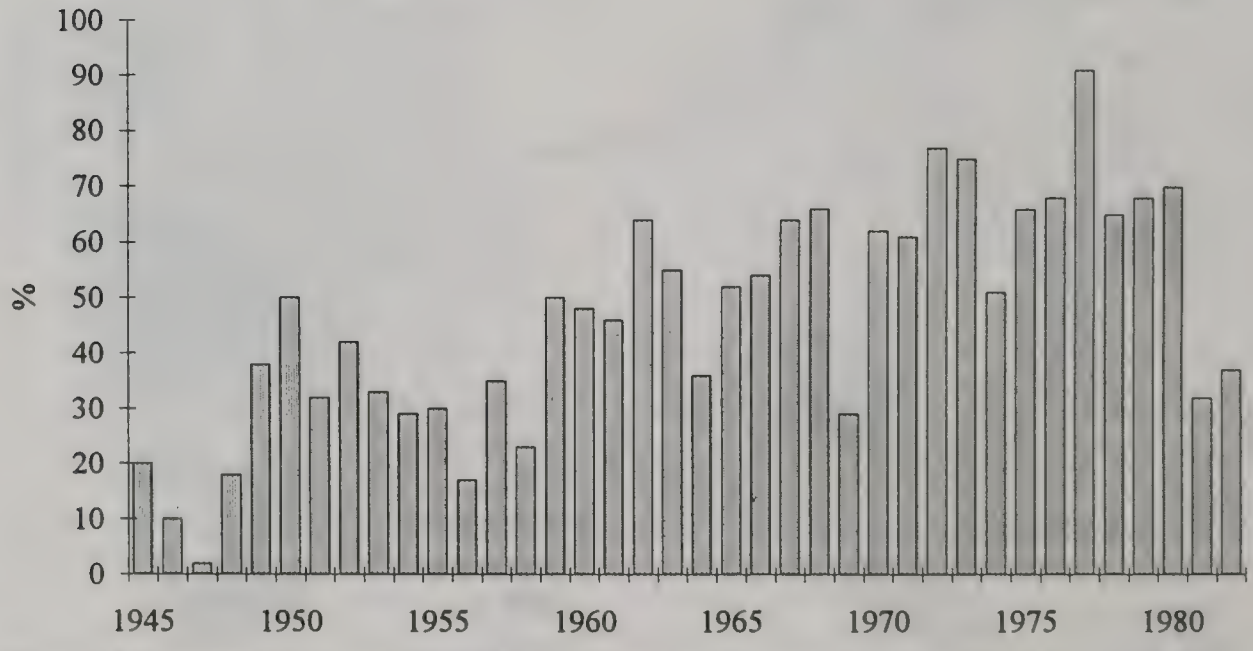

Figure 14. Percentage of cropland tilled in the fall in Illinois in recent decades. Source: Illinois Department of Agriculture.

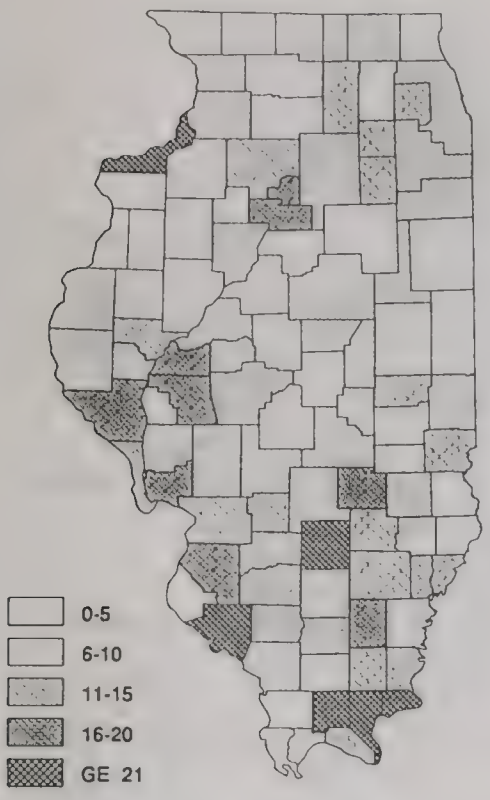

Figure 15. Percentage of cropland for which no-till planting methods were applied in 1987. Source: U.S. Department of Agriculture, Soil Conservation Service.

(Figure 24). Since 1985, over 96% of the corn and soybean acreage receives at least one application of herbicide (Pike et al. 1991). In the United States, herbicides now constitute 90% by weight of all pesticides used in agriculture (National Research Council 1989).

Data from the U.S. Department of Agriculture (Figures 23 and 25) show that the acreage treated with at least one insecticide for any insect pest rose to over 40% in the late 1980s and never exceeded 60%. Nevertheless, data collected by University of Illinois researchers and presented in Table 1 show a different trend for soil insecticides, which typically dominate corn insecticide treatments. In the late 1960s, 70% of corn in Illinois was treated with a soil insecticide. The percentage is now under 30% in the 1990s, due to educational and insect monitoring programs. In addition, the dosages of chemicals applied per acre decreased during the 1980s (National Research Council 1989).

Almost all previous surveys described only the amount of land treated with pesticide applications. The amount of farmland treated with various chemicals is only a crude measure of chemical disturbance. The biochemical properties of such compounds and the amounts of active ingredient applied are of critical importance. The

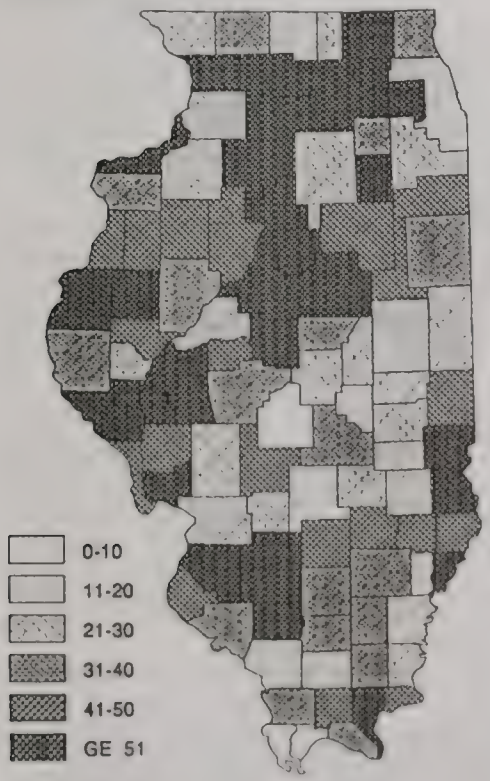

Figure 16. Percentage of cropland for which conservation tillage was applied in 1987. Source: U.S. Department of Agriculture, Soil Conservation Service.

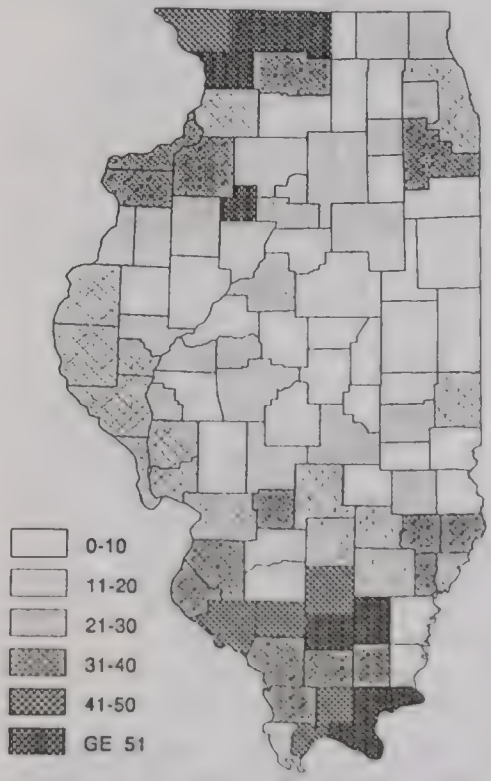

Figure 17. Percentage of farmland with highly erodible soils. Source: U.S. Department of Agriculture, Soil Conservation Service.

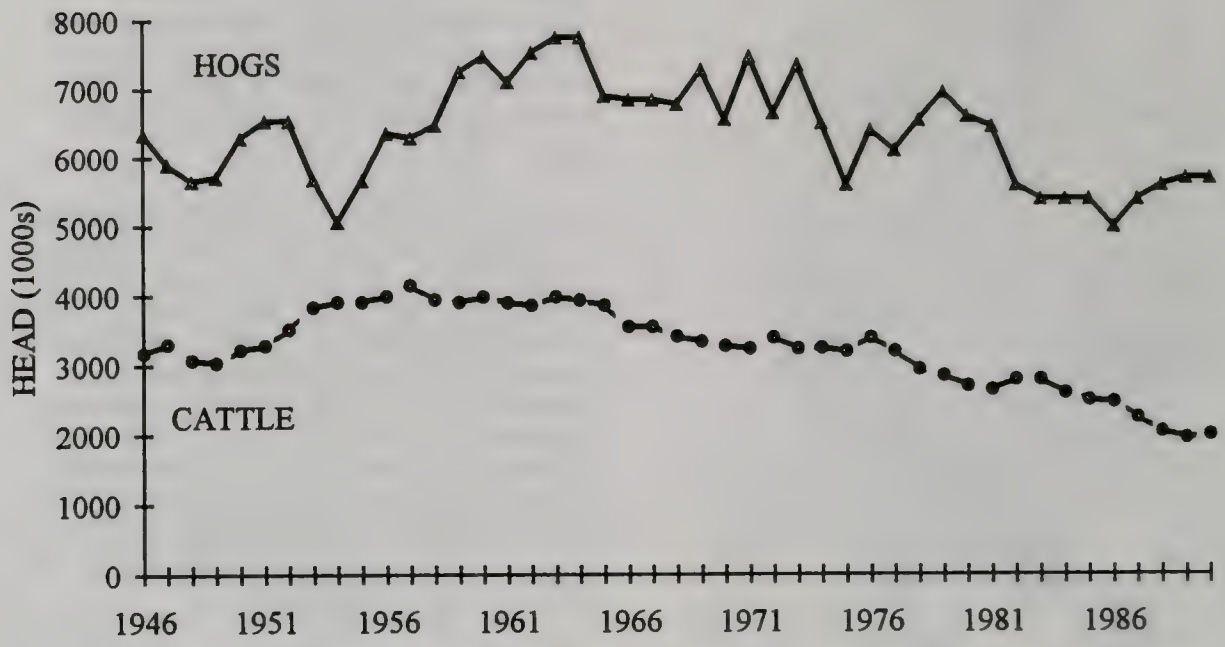

Figure 18. Number of cattle and hogs on Illinois farms, 1945–1990. Source: Illinois Department of Agriculture.

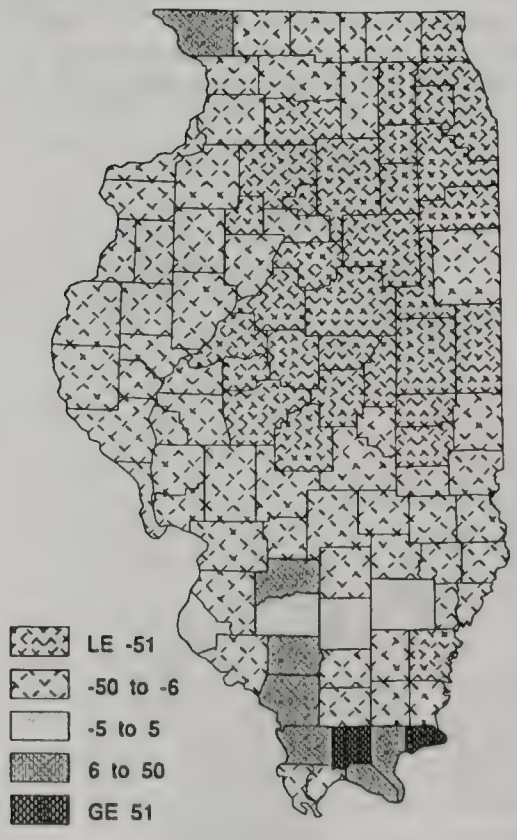

Figure 19. Percent change in the number of cattle in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

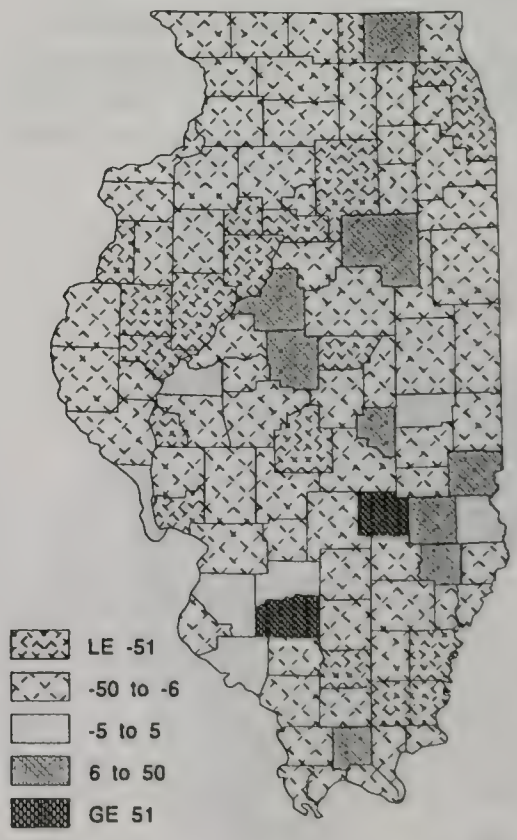

Figure 20. Percent change in the number of hogs in Illinois counties, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

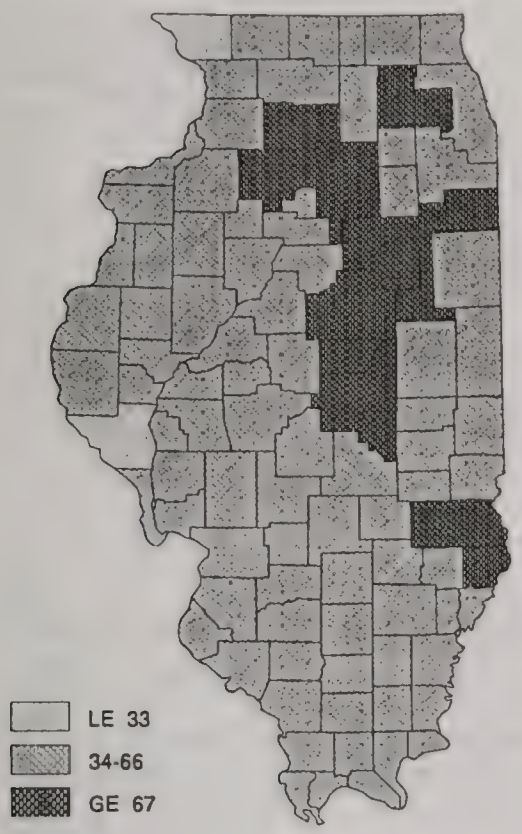

Figure 21. Percent decrease in farmland grazed, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

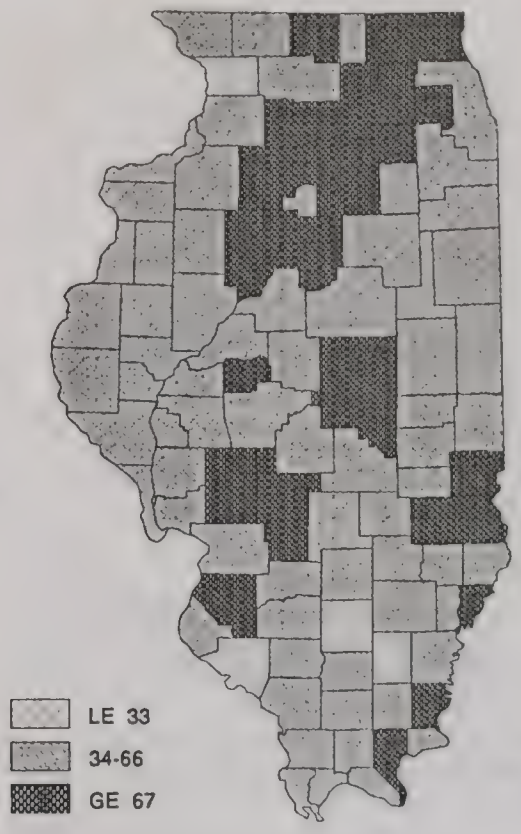

Figure 22. Percent decrease in woodland grazed, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

amounts of active ingredients applied in corn and soybeans (lb/acre) have been decreasing since the late 1970s (National Research Council 1989).

Knowing how much active ingredient is applied per treatment per acre and how many treatments and acres are involved is critical to understanding contamination by pesticides. Unfortunately, this information is not currently available for Illinois farmland.

In general, the toxicity of pesticides and their metabolites to nontarget organisms, and indirect effects, remain poorly understood. A plethora of compounds are used, and the list of approved compounds continues to increase.

Trends in Nitrogen and Soils

Illinois has the best soils for crop production in the world. However, because of soil type and slope of the land, many farms have highly erodible soils (Figure 17). Erosion by wind or water runoff moves soil around the same farm, from farm to farm, and from farm to streams and lakes. Sedimentation of water resources is a major problem in Illinois (see chapter in this volume on lakes and impoundments).

At present, Illinois has one of the highest rates of inorganic fertilizer application in the Midwest. Since 1982, nitrogen, phosphorus, and potassium fertilizer use has been approximately 150, 80, and 80 pounds per acre, respectively, in Illinois, according to the Illinois Department of Agriculture. Field corn receives the vast majority of the nitrogen fertilizer. Figure 26 shows how fertilizer use has changed over the past 30 years in the counties of Illinois. Extensive use of inorganic fertilizers has led to serious nonpoint-source pollution of water resources in Illinois (see volume 2 of this report). Because nitrogen is water-soluble, the potential for runoff of this nutrient is very high.

Biological, chemical, and physical processes associated with agriculture have a profound effect on nutrient cycling in soils. Compared to nutrient cycles in natural ecosystems, the physical and chemical processes associated with current intensive row cropping systems

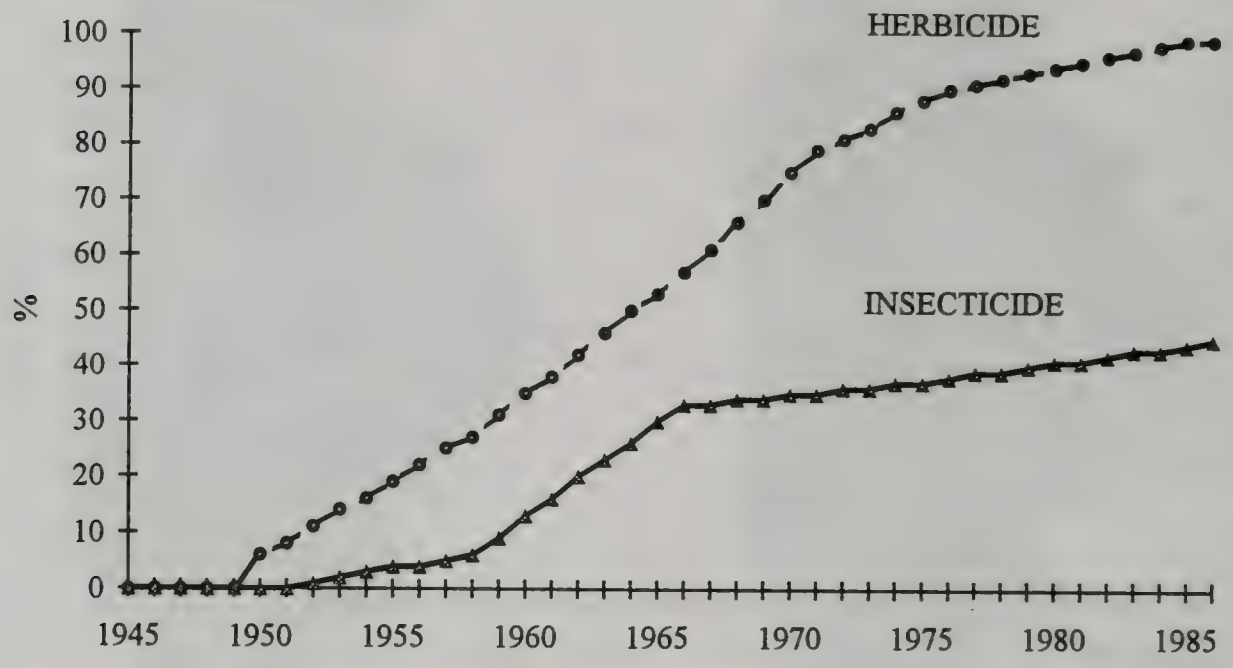

Figure 23. Estimated percentage of corn acreage receiving pesticide applications in Illinois, 1945–1985. The curves were drawn to fit data collected in 1952, 1958, 1966, 1971, 1976, and 1985. Source: U.S. Department of Agriculture.

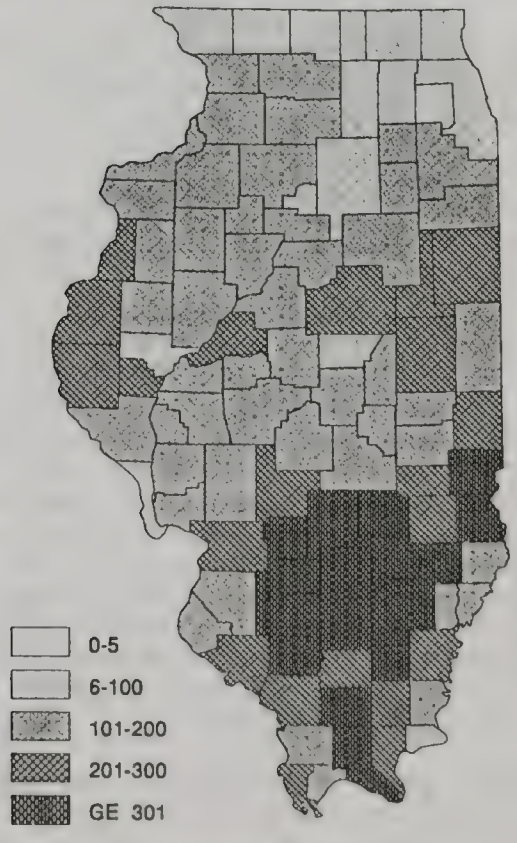

Figure 24. Percent change in number of acres of farmland receiving herbicide, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

render soils relatively vulnerable to loss of mineral nutrients such as nitrogen through soil erosion, volatilization, and mineral leaching. Soil organic matter has been extensively depleted through accelerated decomposition and harvesting of chemicals with removal of crop in the annually cropped soils of Illinois. Soil depletion has led to reliance on inorganic fertilizers because of the reduced capacity of soils to accumulate and store nutrients and the high demand for nitrogen and other nutrients by crops such as corn.

See Volume 2 of this report (the volume on water resources) for information on the effects of movements of inorganic nutrients relative to open water, well water, and municipal water supplies in Illinois.

Trends in Wildlife and Habitats

Agriculture has been the dominant influence on the flora, fauna, and quality of terrestrial and aquatic habitats in Illinois since the early 1800s. Ironically, the influence of agriculture on biodiversity in recent decades is not well documented. At present, 356 species of plants and 144 animals are considered threatened or endangered in Illinois. Many of these species are presently documented on natural areas or in other habitats that are not farmed (see chapters in this volume on forests, wetlands, and prairies). Agriculture

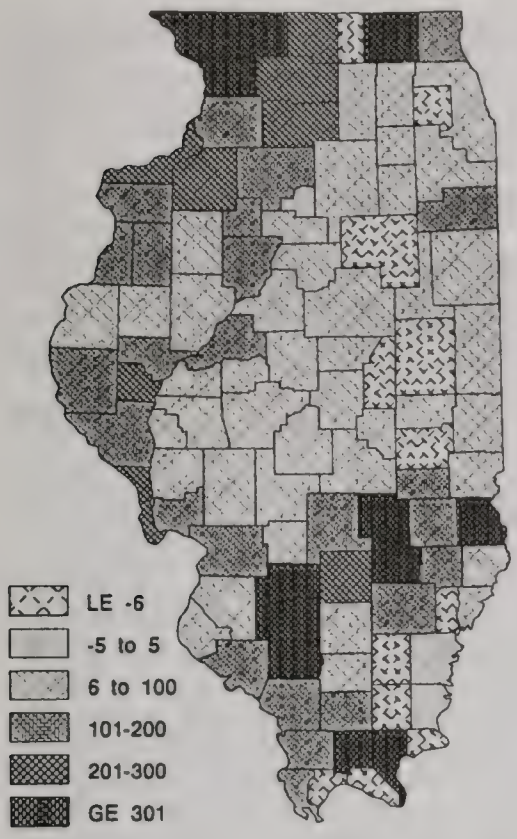

Figure 25. Percent change in number of acres of farmland receiving insecticides, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

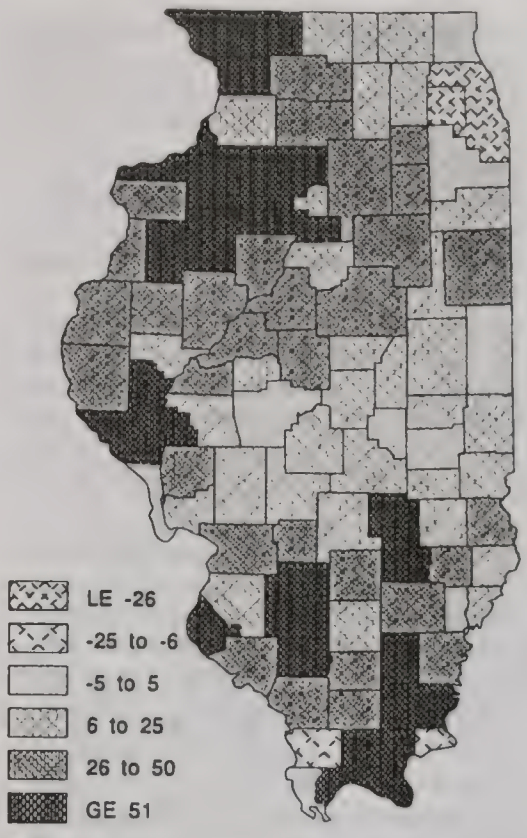

Figure 26. Percent change in number of acres of farmland receiving commercial fertilizer, 1964 to 1987. Source: U.S. Department of Commerce, Bureau of the Census.

Table 1. Percentage of corn acreage treated with soil insecticide in Illinois, 1969–1990.

Source	1969	1972	1976	1978	1982	1985	1988	1990
Kuhlman et al. 1989	70	60	56	65	53	42	32	–
Pike et al. 1991	–	–	–	64	47	42	30	29

may affect the survival of threatened and endangered species through habitat destruction, alteration of the physical and chemical properties of streams, and the fragmentation of wooded and grassland tracts. Moreover, where natural areas hosting rare species are bordered by agricultural environments, the flora and fauna are potentially subject to farming disturbances in the surrounding land mosaic.

The status of threatened and endangered species on agricultural lands is for the most part unknown. In addition, the potential impact of agriculture on the remaining threatened and endangered species in the coming decade has not been assessed.

Declines in the abundance of upland game since the 1960s (Figure 27) are a case study of how intensive agriculture has negatively affected habitat for many wildlife species traditionally common to the farm landscapes of Illinois. The declines in upland game populations and other farmland wildlife associated with habitat loss are due to expanded row crop production and the reduction in the amount of oats, perennial vegetation such as hay, and uncropped farmland, including wetlands, savannas, and permanent pasture. Farm programs diverting cropland from production were important for establishing upland wildlife habitat during the 1950s and 1960s. The Conservation Reserve Program of the 1980s has also provided wildlife habitat. However, millions of acres of cropland diverted from production under annual contract during

the 1980s were poorly managed, with minimal benefits to wildlife and soil conservation (R. Warner, Illinois Natural History Survey, unpublished data).

Although most upland wildlife species once common in agricultural settings have sharply declined over the past two or three decades (Figure 27), there are notable exceptions. Some species have adapted to the changes in farm practices. For example, white-tailed deer, although associated with woodland, use cropland for many life-sustaining activities. Numbers of deer have increased dramatically in recent decades, to the point that this species is a major game animal and in some areas has become a pest (see chapter in this volume on forests).

The harvest of upland game such as pheasant, rabbit, and quail has been declining in recent decades (Figure 27), reflecting the declining abundance of such wildlife on farmland. Moreover, recreation associated with such hunting has also declined over the past 20 years (Figure 27). In spite of the declines, recreation associated with upland game brings millions of dollars annually to local economies in Illinois. Many appreciative forms of wildlife-associated recreation would likely expand if wildlife were more diverse and abundant. However, the extent to which future habitat improvements on farmland can be linked with economic gains to farming communities via increased consumptive and nonconsumptive wildlife recreation is poorly understood. Trends in habitat quality, responses by wildlife, and recreation associated with wildlife will need to be monitored.

Landscape Function

Agricultural environments have several key landscape functions from the perspective of natural areas and other uncommon land forms. First, some of these natural or semi-natural areas are used for agricultural purposes and, thus, are directly affected by farm practices. Second, most unfarmed natural and semi-natural areas such as wetlands, woodlands, savannas, and grasslands persist in predominately agricultural land mosaics in Illinois. Thus, natural habitats are spatially linked by agricultural land; farmland can serve as a corridor for movement of animals and plants. Third, agricultural practices can affect flora and fauna in natural areas adjacent to agricultural lands (e.g., by the exposure of flora and fauna to pesticides). Fourth, the spatial configuration of cover types and land forms in farm mosaics affects the hydrology and movements of chemical, biological, and physical elements within and across regions. In general, these spatial dynamics are poorly understood. The importance of landscape design, and the overlay of farm practices, has not been extensively studied.

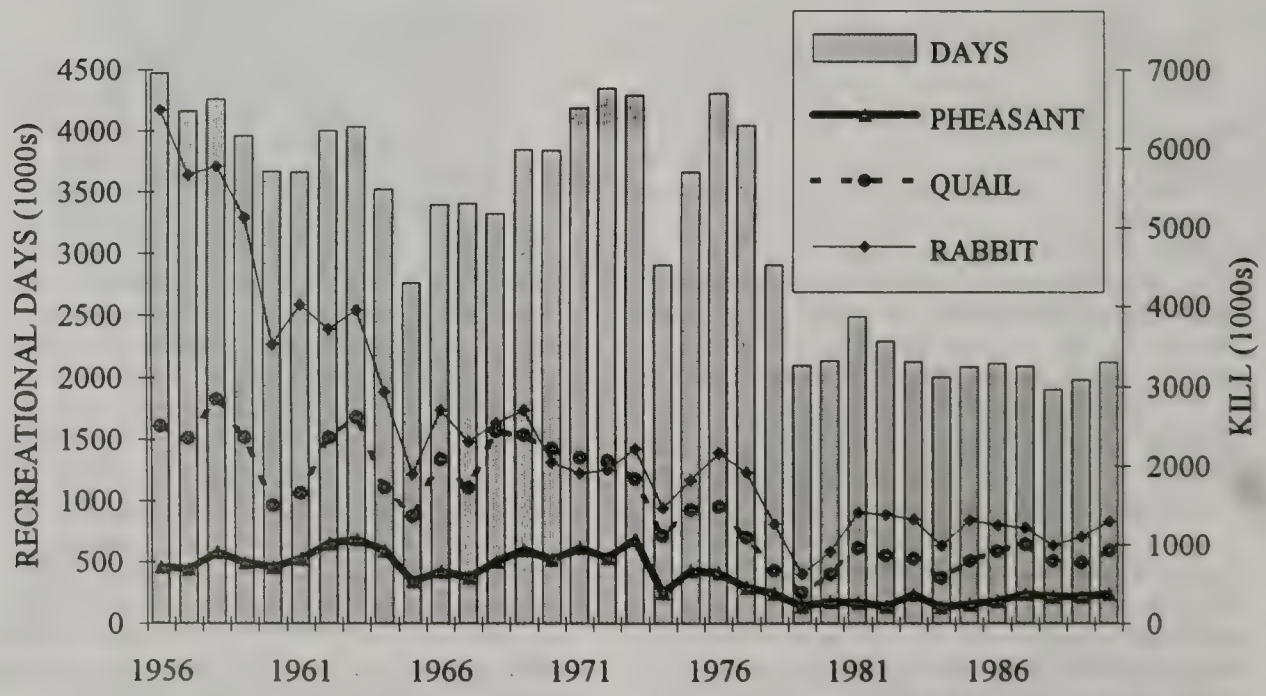

Figure 27. Number of pheasant, quail, and rabbits harvested by hunters in Illinois and the number of recreational days associated with hunting these species. Source: William Anderson, Illinois Department of Conservation.

SOURCES OF STRESS ON AGRICULTURAL LANDS

Some stresses have already been identified. Tillage disturbs the soil and tends to increase soil erosion. Pesticide use can stress nontarget organisms such as beneficial insects, earthworms, and wildlife. Inputs of nitrogen fertilizer produce an imbalance of nitrogen in soils already stressed by tillage, tractor compaction, and the removal of vegetation. In the next two sections, two classes of pests will be discussed.

Insects

It is important to evaluate the status of insects and related arthropods because they constitute the largest group of organisms in the world, they usually are very mobile, and they often are categorized as beneficial or harmful to agriculture, forests, and human health. For example, many of the most important pests in Illinois migrated to this state over the past 30 years (Table 2). At least nine species of these insects, mites, and ticks are now established as pests, and another 13 species may become important pests in the future. An additional 19 species introduced to Illinois are not expected to become pests under any circumstances (Table 2). To counteract the populations of pests in agriculture, eight species of insects have been introduced over the past 30 years to act as biological control agents. Before 1960, many biological control agents were introduced to attack the European corn borer; after 1960 most of the natural enemies were directed at alfalfa pests (Table 2).

Figure 28 shows the trend in immigration of new insects into Illinois. Every five years or so at least one important pest species comes to Illinois. For example, from 1960 to 1964, the western corn rootworm and the alfalfa weevil arrived. During 1965–1969, the cereal leaf beetle invaded the state. In 1985-1989, the honey bee tracheal mite, the varroa mite (another enemy of honey bees), and the Asian tiger mosquito all moved into Illinois.

Integrated pest management has been successful in using host plant resistance and biological control to suppress many of these pests, especially in agriculture. Nonetheless, chemical control is still a widely used option for economic reasons in agriculture and for public health reasons in mosquito control. Even when pest populations are managed well, the annual pressure from new generations of pests may still be significant. Two examples of important pests emphasize this point.

Table 2. Partial list of insect species new to Illinois since 1960.

Established species of agricultural, medical, or veterinary importance (9 species)

- *Oulema melanopus*, cereal leaf beetle
- *Hypera postica*, alfalfa weevil
- *Diabrotica virgifera*, western corn rootworm
- *Acarapis woodi*, honeybee tracheal mite
- *Varroa jacobsoni*, varroa mite
- *Aedes albopictus*, Asian tiger mosquito
- *Ixodes scapularis*, deer tick
- *Amblyomma americanum*, lone star tick

Species with potential economic or health consequences, currently with limited distribution or abundance (13 species)

- *Lymantria dispar*, gypsy moth
- *Baris lepidii*, imported crucifer weevil
- *Nezara viridula*, Southern gree stinkbug
- *Amblyomma maculatum*, Gulf Coast tick
- *Hyadaphis tataricae*, honeysuckle aphid
- *Bemisia tabaci*, sweetpotato whitefly
- *Diatraea grandiosella*, wouthwestern corn borer
- *Periplaneta fuliginosa*, smokybrown cockroach
- *Calomycterus setarius*, imported longhorned weevil
- *Cyrtepistomus castaneus*, Asiatic oak weevil
- *Cylas formicarius elegantulus*, sweetpotato weevil
- *Grapholitha prunivora*, lesser appleworm
- *Trogoxylon prostomoides*, a powder-post beetle

Species with noneconomic or unknown consequences (19 species)

- *Hexarthrum ulkei*, a weevil
- *Dermestes peruvianus*, a dermestid beetle
- *Anthrenus coloratus*, a dermestid beetle
- *Ceuthophilus seclusus*, a camel cricket
- *Sternostoma tracheacolum*, a nasal mite of birds
- *Paravespula germanica*, German yellowjacket
- *Vesap crabro germana*, European giant hornet
- *Herculia intermedialis*, a pyralid moth
- *Nalepella halourga*, an eriophyid mite
- *Rhabdophaga swainei*, spruce bud midge
- *Alphitobius laevigatus*, black fungus beetle
- *Pentamerismus taxi*, a false spider mite
- *Amblytylus nasutus*, bluegrass plant bug
- *Dolerus wanda*, a sawfly
- *Neodiprion excitans*, blackheaded pine sawfly
- *Monochamus scutellatus*, whitespotted sawyer
- *Neoclytus muricatulus*, a long-horned beetle
- *Xylotrechus sagitattus*, a long-horned beetle
- *Caloptilia azaleella*, azalea leafminer

Beneficial species, including those released for biological control (8 species)

- *Bathyplectes curculionis*, an alfalfa weevil parasite
- *Microctonus anurus*, an alfalfa weevil parasite
- *Microctonus colesi*, an alfalfa weevil parasite
- *Tetrastichus incertus*, an alfalfa weevil parasite
- *Coccinella septempunctata*, an aphid predator
- *Patasson luna*, an alfalfa weevil parasite
- *Biolysia tristis*, a parasite

List compiled by the Illinois Natural History Survey, Center for Economic Entomology, April 1992

The European corn borer has been an important pest in Illinois since it migrated to the state more than 50 years ago. The average annual loss of corn grain due to corn borer in Illinois was estimated in the 1980s at $50 million. Figure 29 shows the pattern of population fluctuations over the state since 1943. Generally, more than two corn borers remaining in a stalk during the fall sampling period represent damaging populations in Illinois corn fields. Of course, when the average for the state is near two per stalk, many fields have many more than the average. Figure 29 demonstrates that the corn borer populations have not declined during the past 10 years.

The gypsy moth is a serious defoliator of urban and forest trees in the northeastern United States. In Illinois, the moths have been trapped off and on over the past 20 years, usually in very low numbers. Most have been caught in the northeast part of the state around Chicago (Figure 30). This pest may be established in this area or the traps may be picking up male moths that have flown far away from areas infested by flightless females. The values in Figure 30 are lower than those found in the heavily infested areas in the Northeast. Based on 1992 trapping, 18 sites comprising 400 acres required treatment in 1993.

To establish a viable population, female and male larvae must slowly enter a new region along an invasion front. The wave of infestation is currently moving through Michigan (Figure 31). This wave is expected to reach Shawnee National Forest in southern Illinois in the year 2000. A faster means of migration over long distances can occur when the gypsy moth hitches rides on motorized vehicles that have passed through infested areas. Thus, a recreational vehicle that leaves Michigan in July and travels to an Illinois forest may promote the spread of the gypsy moth. Swofford et al. (1988) predicted that almost all oak-hickory woodlands in the state will be in danger of extensive defoliation by the gypsy moth. As the chapter in this volume on forests indicates, many of the major forests in the state are oak-hickory. Thus, the invasion of the gypsy moth should be considered a major development.

Weeds

The control of weeds has been a major concern for agriculture for over a century. Because weeds are an economic threat to crops, farmers use chemical and mechanical means to control them. The most important agricultural plant pests are listed in Table 3.

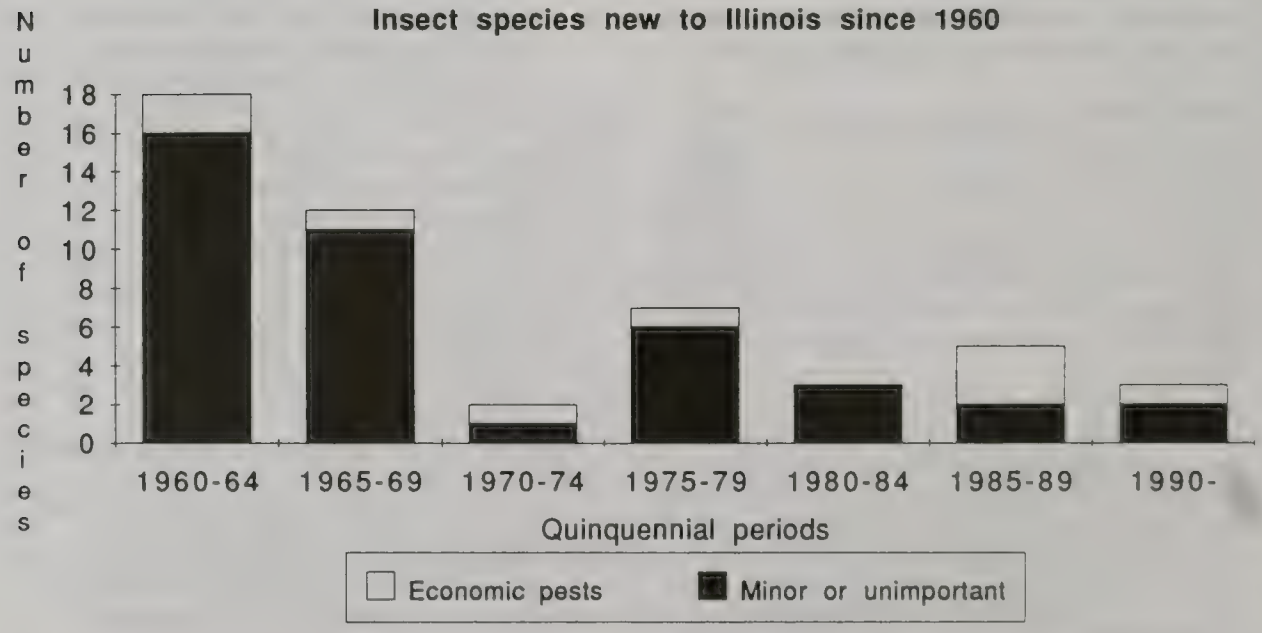

Figure 28. Number of insect species arriving in Illinois in five-year intervals since 1960. Source: Illinois Natural History Survey.

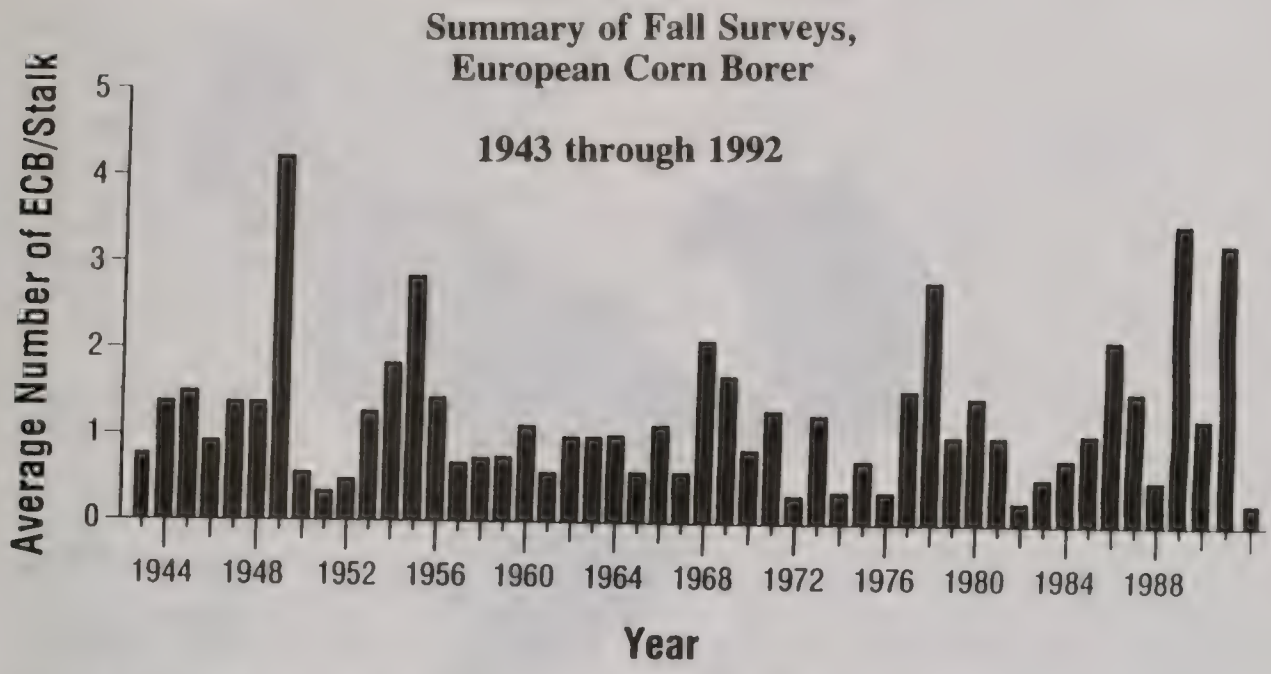

Figure 29. Trends in the number of European corn borers in Illinois, 1943–1992. Source: Illinois Natural History Survey.

CONCLUSION

Agriculture is the most important single industry in Illinois. With over 80% of the land area in farms, agriculture has a pervasive influence on the terrestrial and aquatic environments of the state. Agriculture and environmental quality have changed dramatically since World War II in conjunction with emerging farming practices and associated technologies. Agricultural practices have led to serious environmental problems, and these problems have generally become worse in recent decades. For example, the use of inorganic fertilizers and herbicides has increased dramatically. The extensive use of inorganic fertilizers has allowed for intensive row crop monocultures that are not efficient in terms of nutrient and energy cycling. Intolerably high soil erosion rates and water quality problems have become widespread where intensive row cropping has encroached on marginally suitable soils, and soils have been highly disturbed during tillage and planting.

The expansion of row crop farming has accelerated the loss of wildlife habitat, contributing to a decline in the abundance of most wildlife species and a loss in biodiversity—trends that have become progressively worse since the early 1800s. Also, as agricultural environments have become seriously degraded, movements of soil and chemicals from farmland to

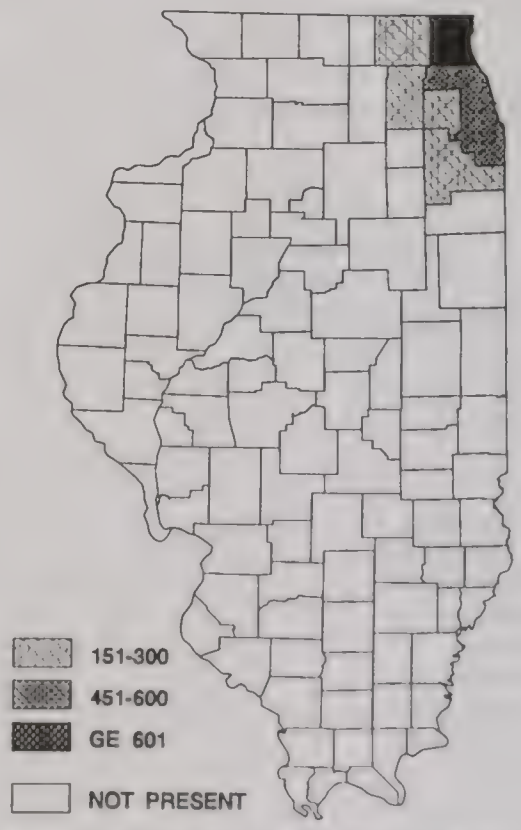

Figure 30. Distribution of gypsy moths in Illinois, 1992. Values indicate number of gypsy moths trapped per county. Source: National Agricultural Pest Information System database, USDA-APHIS/PPQ.

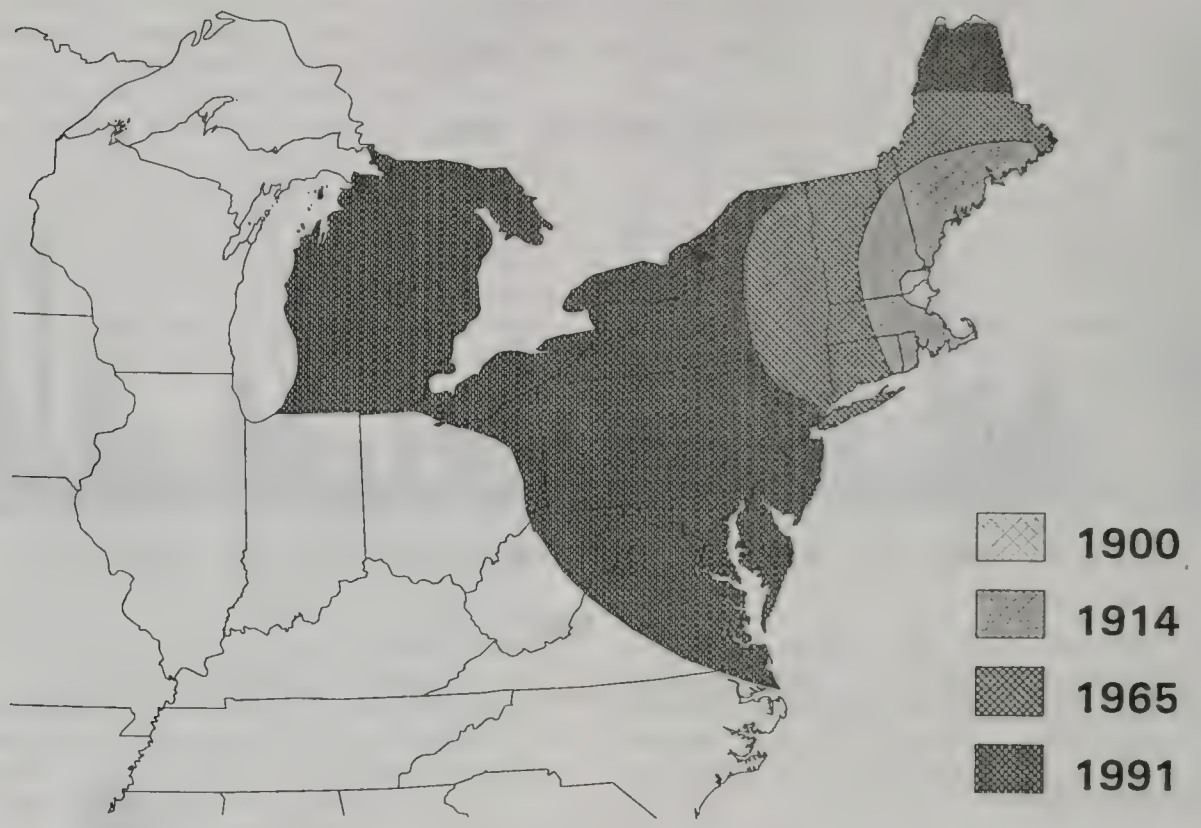

Figure 31. Spread of gypsy moth defoliation in the United States, 1900–1991. Source: U.S. Forest Service.

Table 3. Major agricultural plant pests in Illinois. Plants are listed in order of descending economic importance for weed control efforts.

Velvetleaf
Foxtail
Cocklebur
Pigweed
Smartweed
Giant ragweed
Annual morning glory
Common ragweed
Lambsquarter
Jimsonweed
Hemp dogbane
Milkweed (common)
Black nightshade
Fall panicum
Shattercane
Yellow nutsedge
Canada thistle

Source: Pike et al. 1991.

underground water supplies and tributaries has led to serious problems of siltation and chemical alterations in nearly all aquatic environments in the state.

During the past decade, however, some significant progress has been made in addressing environmental problems related to agriculture. For example, the adoption of conservation tillage methods has become widespread and continues to increase. There is also evidence that insecticide use has declined statewide as integrated pest management practices have been adopted.

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NOTES ON SOURCES OF INFORMATION FOR FIGURES

Illinois Department of Agriculture: Published and unpublished data regarding farming in Illinois were obtained from the Illinois Department of Agriculture, Springfield. For example, annual trends in crop production are published in reports such as *Illinois Agricultural Statistics: Field Crops by Counties, 1975–1987* (Illinois Department of Agriculture Bulletin 90-2). Annual trends in livestock production are published in reports such as *Illinois Agricultural Statististics: Livestock and Poultry by Counties, 1975–1988* (Illinois Department of Agriculture Bulletin 90-3).

U.S. Department of Agriculture, Soil Conservation Service: State and national data were acquired from Stephen J. Brady, Soil Conservation Service/Forest Service, Rocky Mountain Forest and Range Experiment Station, 3825 E. Mulberry, Ft. Collins, CO 80524-2098 and from Richard Dickerson, Soil Conservation Service, 1902 Fox Drive, Champaign, IL 61820.

U.S. Department of Commerce, Bureau of the Census: The Bureau of the Census is the source of census of agriculture data. For example, the 1987 data are published in U.S. Department of Commerce. 1989. Vol. 1. Geographic area series. Part 51. United States summary and state data. AC87-a-51. Bureau of the Census, Washington, D.C. 414 p. The data and supporting documents can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

WETLANDS

SUMMARY

Wetlands in Illinois and elsewhere have tremendous biological value. They provide essential habitat to a wide variety of flora and fauna; they can be effective nutrient and sediment traps; they can modify flood waters; and they are sources for groundwater recharge and discharge. Wetlands also provide a multitude of substantial economic benefits, including recreation and improved water quality. Although wetlands are an important and productive ecosystem and are becoming increasingly appreciated, little information, other than descriptive information, on Illinois wetlands is available to document trends in their numbers as well as trends in their plants and animals.

Less than 50% of the presettlement wetlands in the lower 48 states exist today. Primarily because of drainage for agricultural purposes, only 917,765 acres (371,414 ha) of natural wetlands remained in Illinois by the 1980s, or about 10% of an incomplete estimate of 9.4 million acres (3.8 million ha) of original wetlands. Only approximately 6,000 acres (2,429 ha) of the wetlands remaining in Illinois were high quality and undisturbed. Thus, Illinois has lost at least 90% of its presettlement wetlands, and this loss occurred at an estimated rate of 0.5 to 1.0% per year from the mid-1950s to the mid-1970s. The remaining natural wetlands occupied about 2.6% of Illinois in the 1980s. Furthermore, many of the remaining natural wetlands have been severely reduced in quality because of sedimentation, pollution, or other impacts of modern society. Existing wetlands, including both natural and modified wetlands, occupied 1,253,891 acres (507,443 ha) of Illinois in the 1980s, or about 3.5% of the state. Palustrine wetlands represented 93% of Illinois wetlands in the mid-1980s. Relatively undisturbed remnants of the rare wetland communities of seeps, pannes, bogs, and fens were represented by less than 350 acres (142 ha) each.

Wetland plants compose about 32% (952 of 2,959 species) of the total flora (both native and non-native) of Illinois and 42% (862 of 2,069 species) of the native flora of the state. Additionally, more than 18% of the native wetland plant species in Illinois are listed as threatened or endangered. Approximately 35 wetland plant species appear to have become extirpated from the state. About 9.4% of the wetland flora of Illinois consists of non-native species.

Most of the birds, mammals, amphibians, and reptiles in Illinois use wetlands. As many as 266 species of birds can use wetlands in Illinois during some stage of their life cycle. The numbers of nesting colonies of great blue herons and great egrets have increased since 1983. The numbers of great blue herons, great egrets, and black-crowned night herons have also increased in the state since 1983. Unfortunately, the numbers of many species of ducks migrating through Illinois have been decreasing over the past 40 years; the decreases are a result of lower continental numbers of many of these species and the degradation and the loss of wetlands and, consequently, the waterfowl food provided by wetlands in the state. Thirty of the 43 species of endangered and threatened birds in Illinois are strongly associated with wetlands. Numbers of endangered double-crested cormorants and bald eagles in Illinois have steadily increased since the federal prohibition of certain pesticides in the 1970s. In addition to over 2,000 bald eagles observed wintering in Illinois in 1992, there were 17 nests from which 16 eaglets successfully fledged.

Of the 59 species of mammals in Illinois, at least 36 use wetland habitats. Eight of the 10 endangered and threatened mammal species in Illinois depend upon wetlands. Thirty-seven of the 41 species of amphibians in Illinois use wetlands, and all three species of amphibians that are listed as endangered or threatened in Illinois depend upon wetlands. Of the 60 species of reptiles in Illinois, at least 47 utilize wetlands. Seven of nine species of reptiles listed as endangered or threatened in Illinois use wetlands. Twelve of the 29 endangered and threatened fish species in Illinois occur in wetlands or use them for spawning. Overall, of the 94 species of vertebrates listed as threatened or endangered in Illinois, and 64% utilize wetlands, at least for some part of their life.

The current abundance and distribution of many wetland plants and animals is only a remnant of what the European explorers and early settlers experienced. Unfortunately, the trends in the populations of many

animals that depend on wetlands are not definable because of inadequate baseline or long-term data.

Several federal and state governmental programs are available to reduce continuing wetland loss and degradation. Nonetheless, a consistent, enforceable national protection policy for wetlands is necessary. Other needs include the determination of economic values for the functions of wetlands, the development of methods to assess the results of wetland restoration and creation projects, and the actual evaluation of the outcomes of specific projects. The mitigation of wetland loss through restoration and creation has generated much interest, but few studies have documented the success of created or restored wetlands. Thus far, many wetland creation projects have fallen short of equaling the benefits that natural, high-quality wetlands provide.

The citizens of Illinois and the nation are becoming more aware of the value and importance of their wetland heritage. Knowledge, understanding, and appreciation of wetland systems and their importance must be expanded, more widely disseminated among the general public, and increasingly incorporated into our public policies to insure that this critical ecosystem remains a vital part of our state's natural heritage.

INTRODUCTION

Wetlands are among the most important ecosystems on our planet (Figure 1). Approximately 6% of the land surface of the earth is wetland (Mitsch and Gosselink 1986). Wetlands are generally defined as lands where water saturation is the dominant factor that determines both soil development and the types of plant and animal communities living in the soil as well as on its surface (Wilen and Frayer 1990). Therefore, wetlands are transitional lands between terrestrial and aquatic systems where the land is covered by shallow water or the water table is at or near the surface.

Unfortunately, from colonial times until the past two decades, "wetlands have been regarded as nuisances, wastelands, habitats for pests, and threats to public health" (Wilen and Frayer 1990:182). Consequently, they have been "reclaimed" by draining, clearing, and filling in the name of progress. In recent years, however, wetlands have become more appreciated for their functions as well as for their economic values. The functions of wetlands include regulating the flow of water, storing water, recharging groundwater, filtering and purifying water, trapping sediments, providing

Figure 1. Wetlands, such as this marsh in Tazewell County, are productive and important ecosystems.

habitat for plants and animals, and providing recreational opportunities (Wilen and Frayer 1990). Wetlands have been described as "the kidneys of the landscape" for some of the functions they perform in cleansing our environment (Mitsch and Gosselink 1986).

Wetlands are an important part of our nation's heritage, and they provide benefits for all citizens (Feierabend and Zelazny 1987). Forty-five percent of federally listed threatened and endangered animal species and 26% of the listed plants depend upon wetlands during their life cycle. Additionally, 5,000 species of plants, 190 species of amphibians, and 270 species of birds are estimated to inhabit our nation's wetlands (Feierabend and Zelazny 1987). Approximately 75% of the bird species in North America depend upon wetlands for resting, feeding, or nesting (Steinhart 1990).

One of the more recognizable characteristics of a wetland is that it is continually changing. Water levels may fluctuate daily, seasonally, annually, or over several years. The high degree of biological productivity of wetlands is a result of their dynamic and transitional water levels (Feierabend and Zelazny 1987). Many of the plant and animal species associated with wetlands are adapted to this fluctuating environment. Nevertheless, the quantity and the quality of wetlands are sensitive to human perturbations, and our activities have greatly affected these productive systems (Feierabend and Zelazny 1987).

By the mid-1980s, approximately 103.3 million acres (41.8 million ha) of the estimated 221 million acres (89.5 million ha), or about 47%, of wetlands present at the time of colonial America remained in the conterminous United States (Dahl and Johnson 1991). The

remaining wetlands occupy approximately 5% of the land area. Prior to recent legislation, wetlands had been destroyed nationally at a rate of about 1% per year (Mitsch and Gosselink 1986). Ten states, including Illinois, have lost 70% or more of their original wetland acreage (Dahl 1990).

This component of the critical trends report examines wetlands and their associated flora and fauna in Illinois. Unfortunately, the data necessary to analyze trends for these resources are limited. Much of the relevant information is restricted to a relatively short period of time; in many cases data exist for only a single point in time, thereby making reliable determinations of trends difficult or impossible. However, existing data, much of which is descriptive, will provide valuable baseline information for future analyses and investigations of wetlands.

DEFINITION OF WETLANDS

Wetlands are natural communities located along the hydrological gradient between terrestrial (land) and aquatic (water) habitats. Water, or hydrology, is the dominant force that creates and maintains wetlands. Typical wetlands include marshes, swamps, ponds, potholes, bogs, sloughs, wet meadows, mudflats, and river overflows. Some federal agencies currently use the 1987 wetlands delineation as the official means to identify wetlands. In general, wetlands exhibit the following characteristics:

1. The water table (the upper limit of that portion of the ground that is entirely saturated with water) remains at or near the surface, and water covers the land at least part of the year.
2. The soils are hydric (wet for most of the year and low in oxygen).
3. The plants that grow there are adapted to life in water or saturated soil (hydrophytes).

FUNCTIONS AND VALUES OF WETLANDS

Wetlands, like any natural habitat, have an aesthetic quality and interest that merit their preservation, but they also serve us in ways that are essential. Wetlands play a unique and irreplaceable role in maintaining the quality of our water, in controlling floods, and in providing habitat for an incredible diversity of species. Important wetland functions are summarized in Table 1.

Wetland value is an interpretation of the relative worth of a wetland function, and the value can be positive or negative (Feierabend and Zelazny 1987). Wetlands possess substantial economic values. Farber and Costanza (1987) estimated that, depending upon the methodology used, the total social value of wetland ecosystems ranged from $590 to $10,000 per acre. Feierabend and Zelazny (1987) reported that a wetland with an active water-flow regime, such as a seasonally flooded bottomland forest, could have a value of $30,000 per acre or more based upon a holistic method of analysis. The estimated social value of annual benefits expressed as capital value in Massachusetts in 1972 was $59,900 per acre of wetlands, with high levels of benefit related to wildlife, aesthetic value, water supply, and flood control (Gupta and Foster 1975).

The value of the harvest of furbearers in wetlands during the 1974–1975 season exceeded $35 million in the United States (Chabreck 1978). In 1975, recreational fishermen spent $13.1 billion on fishing activities directed toward wetland-associated fishes (Peters et al. 1978). The U.S. Fish and Wildlife Service (USFWS) estimated that 1.9 million waterfowl hunters spent $307 million in 1980 (Feierabend and Zelazny 1987). A recent survey by the USFWS found that more than half of the adult population in the United States participated in a recreational activity related to fish and wildlife during 1991 (Illinois Department of Conservation 1993). According to the survey, more than 98 million Americans age 16 and older contributed $59.5 billion into our nation's economy in 1991 as a result of these activities. Fishing was a favorite pastime, with 34.8 million anglers 16 years and older spending an estimated $25.3 billion, or $700 each, in 1991 for fishing-related activities. There were almost 14 million Americans 16 and older who hunted, thereby contributing about $12.3 billion, or $900 each, to the 1991 economy. More than 76 million American adults engaged in nonconsumptive wildlife-related activities, such as observing and photographing wildlife; nonconsumptive users spent an estimated $7.5 billion on related travel costs, $9.6 billion for equipment, and $1 billion on dues, contributions to wildlife-related organizations, magazines, or other expenses.

In Illinois, the total annual economic impact was recently estimated to be $1.6 billion from fishing and $366 million for hunting, whereas annual nonconsumptive expenditures were estimated to be $893 million (Conlin 1991). The total annual expenditures for fishing, hunting and nonconsumptive recreation in Illinois averaged $2.86 billion in the late 1980s. The average annual harvest of waterfowl in Illinois and the Mississippi Flyway from 1986 to 1990

Table 1. The important functions of wetlands.

Function	Description
Flood conveyance	Wetlands associated with riverine systems serve as floodways transporting flood pulses from upstream to downstream locations.
Erosion control	Wetlands act as reservoirs, slowing water runoff rates and thereby decreasing erosion.
Wave barriers	Wetlands associated with lakes and rivers buffer waves, protecting uplands and shorelines.
Land formation	The accumulation of organic material and detritus over long periods of time forms peat, which gradually fills the wetland basin. By definition, wetlands eventually progress into terrestrial forests. This process is known as autogenic succession.
Flood storage	Inland wetlands store flood waters and slowly deliver water to downstream areas. Floodplain wetlands act on riverine systems by lessening flood peaks.
Sediment control	Vegetation in floodplain wetlands reduces flood velocity, causing sedimentation of particles in flood waters.
Pollution control	Wetlands act as nutrient sinks and settling ponds by removing excess nutrients, chemicals, and particulate matter from runoff and flood waters. Wetland vegetation utilizes excess nutrients for plant growth, and chemicals become entrapped and break down in sediment. Some inland marshes are now being used as tertiary waste (sewage) treatment facilities.
Water supply	Wetlands supply water for human consumption, agricultural irrigation, and industrial processes.
Aquifer recharge	Some wetlands store and then slowly release water, recharging groundwater deposits.
Habitat	Wetlands provide food, cover, loafing, and nesting habitat for a wide array of wildlife species while harboring a large assortment of plant species. Wetlands are home to about one-third of all plant and animal species recognized as threatened or endangered.
Recreation	Wetlands offer many recreational opportunities, such as hunting, fishing, boating, swimming, and wildlife photography.
Education and research	Wetlands provide opportunity for environmental education and scientific research, providing people a better understanding of organisms and their environment.
Food production	The highly productive nature of wetlands makes them a source of food production from marsh vegetation and aquaculture and annual fish and waterfowl harvests.
Timber production	Forested wetlands under proper management are an important source of lumber. Lumber produced from the common baldcypress is highly valued.
Economic	Wetlands have been valued as high as $60,000 per acre ($24,000 per ha) on a multiple-use basis. The 32 million acres (13 million ha) of bottomland hardwoods and common baldcypress swamps of the southeastern United States are worth approximately $8 billion in timber production.
Aesthetic	Many people believe the aesthetic values of wetlands are the most important. Wetlands are beautiful and offer seclusion and tranquility. Wetlands provide observers a vast array of plant and animal life.

was estimated by the USFWS to be 193,500 and 2,942,500, respectively, for ducks and 74,464 and 437,567, respectively, for geese (Havera 1992). The estimated expenditure of Illinois waterfowl hunters during the 1990–1991 hunting season was $44 million, or an average of $743 per hunter (Anderson 1991). The economics of the Canada goose resource in Illinois is important, and it is a multi-million dollar industry in southern Illinois. Indeed, each goose was estimated to represent about $10 to the local economy in southern Illinois (Thomas 1990). During the 1990–1991 season, goose hunting generated an estimated $9.5 million in the Southern Quota Zone of Illinois, about $3.0 million in the Rend Lake area, and approximately $2.5 million in the Tri-County Zone in west-central Illinois (Anderson 1991). Furthermore, economists estimate that each dollar spent turns over 1.5–2.5 times within a community (Thomas 1990).

Canada geese also provide an important nonconsumptive recreation resource. In the mid-1970s, more than 150,000 visitors visited the Horseshoe Lake Refuge in Alexander County each year to enjoy the flocks of wintering Canada geese (Kennedy and Lewis 1977). Personnel at Crab Orchard National Wildlife Refuge have estimated that 275–300 people frequent their observation towers each day to view Canada geese (Thomas 1990). Heinrich and Craven (1992) estimated that about $3.7 million in gross revenue was derived in 1986 from Canada goose viewers and hunters in the Horicon Marsh area of Wisconsin.

Although it is difficult to assign a dollar value to the human experience and enjoyment of a day afield, the economic benefits of wetlands used as aesthetic retreats and for nature study are likely comparable to those derived from commercial uses of wetlands (Feierabend and Zelazny 1987).

DESCRIPTION AND CLASSIFICATION OF WETLANDS

Wetlands can be classified into a variety of forms, each with its own special profile. Swamps (Figure 2) and marshes are perhaps the most familiar. Illinois alone has many different wetland habitats that vary in climate, water supply, soil type, and plant and animal residents. Wetlands range from those in which the soil is saturated for at least part of the year to those with permanently standing water, from wetlands associated with the seasonal changes that occur along a river to those that were formed directly or indirectly by the action of ancient glaciers, from wetlands characterized by organic soils (soils made primarily from decayed plants) to those in which inorganic (mineral) soils predominate, and from grassy wetlands to those that are forested. No two wetlands are alike, and each is an important ecosystem with influence far beyond its perimeters.

In much of the Midwest, wetlands were formed either by the action of glaciers or by rivers. During the last Ice Age, before the retreat of Wisconsinan glaciation about 15,000 years ago, large blocks of ice remnant from the main glacier body melted and formed lakes. In other areas, glaciers merely scooped out shallow depressions that allowed water to accumulate as the ice retreated. Glacial melt-water torrents such as the Kankakee Torrent deposited deep sands locally in the major river valleys in the northern half of Illinois, and these sand deposits support distinctive wetlands.

Wetlands formed by rivers are of several types, including oxbow marshes, floodplain bottomlands, and backwater lakes. When a meandering river changes course and leaves a portion of its channel isolated except during flood, an oxbow pond is formed. In time, this pond fills in and becomes an oxbow marsh. Floodplain bottomlands are created by periodic flooding and include bottomland forest, swamp, and marsh habitats. Backwater (bottomland) lakes form when soil and sand settle out of river currents and form long islands in the river. If such an island becomes high enough to completely separate the side channel from the main river, a bottomland lake is formed. In addition, human activities create as well as destroy wetlands, and some wetlands are produced by impoundments, excavations, and the construction of dikes.

The types of plants and animals found in oxbow marshes and backwater lakes are determined largely by the periodic flooding of these areas by the main river. Because this annual flood is a predictable and recurring phenomenon, many organisms have evolved adaptations that enable them to exploit the seasonally expanded habitat and the food brought in by the flood. Times of low water, however, are just as important as flooding. A low water level concentrates fish into shallow pools where herons and egrets obtain food for nestlings; it exposes mudflats where moist-soil plants grow and produce seeds sought by waterfowl; and it allows soils to drain and be exposed to oxygen, thereby speeding the processes of decay and the recycling of nutrients.

Midwestern wetlands can have either mineral (inorganic) or organic soils. Mineral soils are composed largely of sand, silt, or clay. Organic soils, generally called peat or muck, are formed from plant material that has partially decayed in wet ground that is low in oxygen (anaerobic). These soils are low in oxygen because standing water has partially insulated the plant material from the atmosphere.

Hydrology, the way water is distributed on or below the earth's surface, is important in classifying wetlands. In general, wetlands have two sources of water: surface water from precipitation (rain, snow, ice) and groundwater (the water found below the surface of the soil). A depression that is deep enough to extend below the water table forms a wetland fed by both groundwater

Figure 2. Cypress swamp is an important wetland habitat in the floodplain of the Cache River in Southern Illinois.

and surface water. A depression that does not extend below the water table receives only surface water, such as precipitation and runoff from the surrounding land. Wetlands found on slopes, usually surrounding a lake, pond, or stream, may receive water from several sources, including runoff, floodwater, and groundwater. The length of time the area remains saturated depends on the degree of slope, soil characteristics, and the frequency of flooding or runoff from precipitation.

Contemporary wetlands, particularly undisturbed remnants, provide our best measure of the composition, structure, and dynamics that characterized the original wetlands of Illinois. Wetland dynamics can sometimes only be appreciated with long-term monitoring of the vegetation and hydrology. Such data are generally not available for most wetland community types. One example of the dynamic nature of certain wetland types can be observed from photographs taken of a natural sand pond in Iroquois County (Figure 3) from approximately the same location, on approximately the same date, during 1987 and 1988 (a severe drought year). This sand pond was characterized in 1987 by standing water and populations of pickerelweed (uncommon in Illinois), spatterdock, an uncommon species of bur-reed, and other emergent wetland species. However, during the severe drought of 1988, no standing water was present and the vegetation composition completely changed. Manna grass, absent in 1987, was the dominant species filling the pond basin in 1988. By 1992, bluejoint grass was the common species, and pickerelweed and spatterdock were present again but did not reach full development until much later during the growing season.

The wetlands of Illinois were inventoried in the 1980s as part of the National Wetlands Inventory (NWI) program, a nationwide effort by the USFWS to locate and classify wetland and deepwater habitats. The NWI defines wetlands as areas that are periodically saturated or covered with water less than 6.6 feet (2 m) deep; they must have one or more of the following attributes: hydrophytic vegetation, hydric soils, and saturated hydric conditions or with shallow water inundation at some time during the growing season. The NWI uses the classification system developed by Cowardin et al. (1979).

The NWI was modified and enhanced into the Illinois Wetland Inventory (IWI) to more accurately describe the wetlands of the state (Table 2). The IWI was a joint effort of the Illinois Department of Conservation (IDOC), the Illinois Natural History Survey (INHS), and the USFWS. This computerized geographic database stores spatial or map data (i.e., the location and shape of wetland and deepwater habitats) and descriptive information about each map feature. Every wetland and deepwater feature in the IWI is described by area and perimeter, an NWI code describing the ecological and physical characteristics of the feature, and an Illinois Classification code, which is an alternate description based on the NWI codes. The Illinois Classification code facilitates use of the data and was used for Illinois wetlands for the present report. The Illinois Classification code distinguishes between wetlands and deepwater habitats that are "natural" (i.e., not diked, impounded, dug, or channelized) and those modified or created by human activity (i.e., diked, impounded, dug, or channelized). "Natural" wetlands represent the original or naturally occurring wetlands in the state.

The NWI/IWI is the only existing comprehensive inventory of the wetland resource of Illinois. A recently

Figure 3. Sand Pool in Iroquois County photographed from near the same location about 1 July during 1987 (top) and 1988 (bottom). Changes reflect the dynamic nature of certain wetland types.

completed analysis of the present (1980–1987) status of wetlands (Suloway et al. 1992) is the basis for much of the information presented here on Illinois wetlands .

WETLANDS IN ILLINOIS

During the 1980s, 917,765 acres (371,414 ha) of natural wetlands (2.6% of the total land) were identified in Illinois using the IWI classification (Table 3). Natural wetlands were concentrated in northeastern Illinois and along the rivers in southern Illinois, such as the Kaskaskia, Big Muddy, Little Wabash, Cache and Mississippi (Figure 4). All existing wetlands, including those modified or created by dike, impoundment, digging, or channelization, occupied 1,253,891 acres (507,443 ha), or 3.5% of the state (Figure 5, Table 3). These wetlands are divided into three main categories: palustrine, lacustrine, and riverine.

Palustrine Wetlands

Palustrine wetlands are dominated by vegetation or, if lacking vegetation, they are small and shallow (< 20 acres and < 6.6 feet deep). Wetlands commonly known as marshes, bogs, fens, sedge meadows, wet prairies, swamps, bottomland forest, and ponds fall into this category. In Illinois, 93% of the existing wetlands, including both natural and modified or created wetlands, are palustrine. Four types of palustrine wetlands occur in Illinois: forested, emergent, open water, and scrub-shrub. Forested wetlands, particularly bottomland forest, are by far the most abundant group, representing 60% of the state's total wetlands (and 71% of natural wetlands) (Figure 6). Emergent (shallow marsh/wet meadow and deep marsh) wetlands are the next most abundant (16%), followed by open water (11%), and scrub-shrub (4%) wetlands.

Table 2. Categories of wetland communities, based on the Illinois Wetlands Inventory (IWI) classification. Some rare wetland types are not identified in IWI, and their identification is based upon the Illinois Natural Areas Inventory (INAI).

IWI classification
Palustrine
Forested
Bottomland forest
Swamp
Emergent
Shallow marsh/wet meadow
Deep marsh
Open water
Scrub-shrub
Lacustrine
Riverine
Rare types (INAI)
Bogs
Fens
Seeps and springs
Pannes

Forested Wetlands. Forested wetlands are dominated by woody vegetation. They are differentiated into swamps or bottomland forest based on the duration of the presence of water. Forested wetlands are largely concentrated in southern Illinois, with scattered concentrations along the Illinois, Mississippi, and other rivers (Figure 7).

Swamps are defined by IWI as forested areas in which the woody vegetation is 20 feet (6 m) or more in height and water is present on a permanent or semipermanent basis; the woody vegetation is adapted to prolonged exposure to standing water.

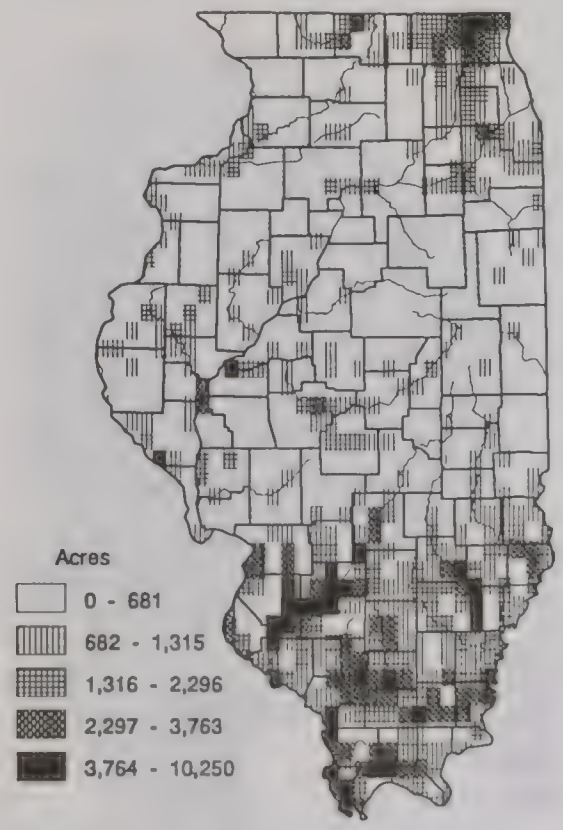

Figure 4. Distribution of natural wetlands by 7.5-minute quadrangle (1980–1987). Source: Suloway et al. 1992.

Table 3. Amounts of various wetland types in Illinois (based on Illinois Wetlands Inventory classification; taken from Suloway et al. 1992).

Habitat	Acres	Percentage of total land	Percentage of total wetlands	Natural		Modified/artificial	
				Acres	Percentage	Acres	Percentage
Palustrine wetlands	1,168,964	3.3	93.2	888,155	76	280,809	24
Forested	773,632	2.2	61.7	661,174	85	112,458	14
Swamp	14,939	0.0	1.2	10,553	71	4,386	29
Bottomland forest	758,693	2.1	60.5	650,621	86	108,072	14
Emergent	201,621	0.6	16.1	172,178	85	29,443	15
Shallow marsh/ wet meadow	162,913	0.5	13.0	146,873	90	16,040	10
Deep marsh	38,708	0.1	3.1	25,305	65	13,403	35
Open water	143,345	0.4	11.4	16,402	11	126,944	89
Scrub-shrub	50,366	0.1	4.0	38,401	76	11,964	24
Lacustrine wetlands	55,568	0.2	4.4	10,307	19	45,261	81
Shallow lake	51,868	0.1	4.1	9,354	18	42,514	82
Shore	2,929	0.0	0.2	422	14	2,507	86
Emergent	772	0.0	0.1	531	69	240	31
Riverine wetlands	29,358	0.1	2.3	19,302	66	10,057	34
Perennial	3,967	0.0	0.3	3,802	96	164	4
Intermittent	25,392	0.1	2.0	15,500	61	9,892	39
Total wetlands	1,253,891	3.5	-	917,765	73	336,126	27

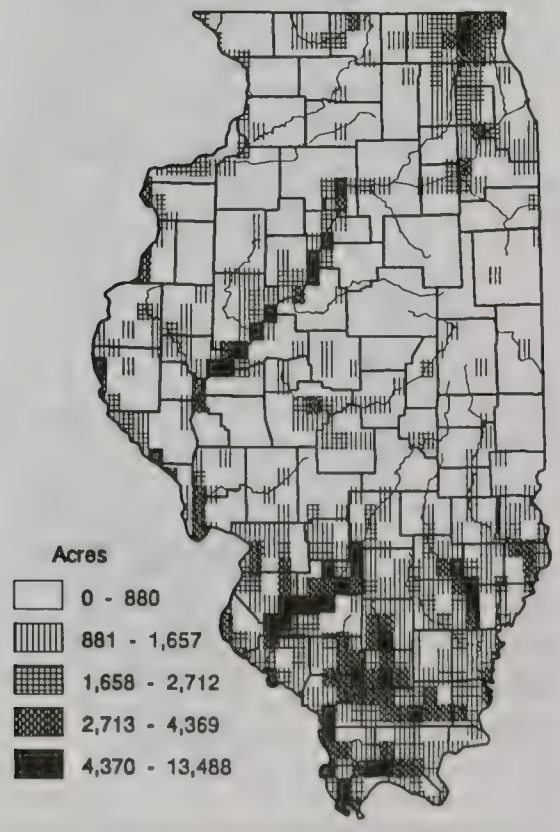

Figure 5. Distribution of total wetlands by 7.5-minute quadrangle (1980–1987). Source: Suloway et al. 1992.

Forested swamps, once common in the southern Midwest, are often dominated by bald cypress and water tupelo. The cypresses may reach prodigious size; in Illinois, the largest is more than 34 feet (11 m) in circumference. Cypresses are also among the oldest living organisms on earth. In southern Illinois, thousand-year-old specimens can still be found. The soil in forested swamps may be either organic or mineral but usually has a topmost organic layer underlain with a mineral soil. Shrub swamps are similar to forested swamps except that less of the vegetation is in the form of trees. Typical plants include willows, Virginia willow (not a true willow), buttonbush, swamp rose, and a few species of dogwood growing in mostly mineral soils.

In Illinois, the most extensive swamps are limited to the southern tip of the state near the northernmost extension for the swamp communities found in the southern United States. The 14,939 acres (6,048 ha) of swamp, including 10,553 acres (4,264 ha) classified as natural, are concentrated in the Cache River basin.

Bottomland or floodplain forests are temporarily or seasonally flooded areas that usually occur along streams and rivers (Figure 7). Because these forests are flooded frequently, they have a lower diversity of tree species than forests located on higher ground. The

understory is typically open, and the ground cover is sometimes dominated by nettles. Rotting logs and woody debris deposited by floodwaters are abundant. Typical trees of Midwestern floodplain forests are silver maple, cottonwood, green ash, hackberry, and sycamore. Several oak species can be found on terraces bordering floodplains. The soils that support these forests are usually mineral.

Bottomland forest, representing 60.5% of the wetlands in Illinois, is the largest single category of the existing wetland habitat in the state. In the mid-1980s, there were 758,693 acres (307,163 ha) (650,621 natural acres; 263,409 ha) of bottomland forests in Illinois. Concentrations of bottomland forests are found along the Illinois, Kaskaskia, Big Muddy, Cache, Little Wabash, and Mississippi rivers; much of this resource is located in the southern third of the state (Figure 7).

Emergent Wetlands. Emergent wetlands are dominated by erect, rooted, herbaceous hydrophytic vegetation—for example, sedges, grasses, and numerous species of forbs. Emergent wetlands are most prevalent in northeast Illinois (Figure 8). Vegetation may remain visible throughout the year or die back in the nongrowing season. Examples include sedge meadows dominated by tussock sedge, wet prairie dominated by cord grass, and marshes. Water depth in marshes ranges from zero (saturated soil) to 6.6 feet (2 m) by NWI definition. In Midwestern marshes, both floating-leaf plants (e.g., water lily) and submerged aquatic plants (e.g., pondweed) are frequently associated with cattails, an emergent species. The soils that underlie marshes are sometimes mineral but are often covered by muck (organic sediment).

Marshes are highly productive habitats in which hundreds of species of birds, insects, and other wildlife spend most of their lives. Productivity in any ecosystem is usually measured in terms of the living things that it produces (biomass). Two factors account for the high productivity of marshes. One is the ability of marsh plants to capture large amounts of energy from the sun and transform and store much of it as chemical energy in the form of plant tissue. The other is the efficient recycling of nutrients already produced, recycling accomplished as dead plants and animals decompose and become nutrients used by living organisms.

The IWI classifies emergent wetlands into two categories: shallow marsh/wet meadow (where standing water or soil saturation is present for brief to moderate periods during the growing season) and deep marsh

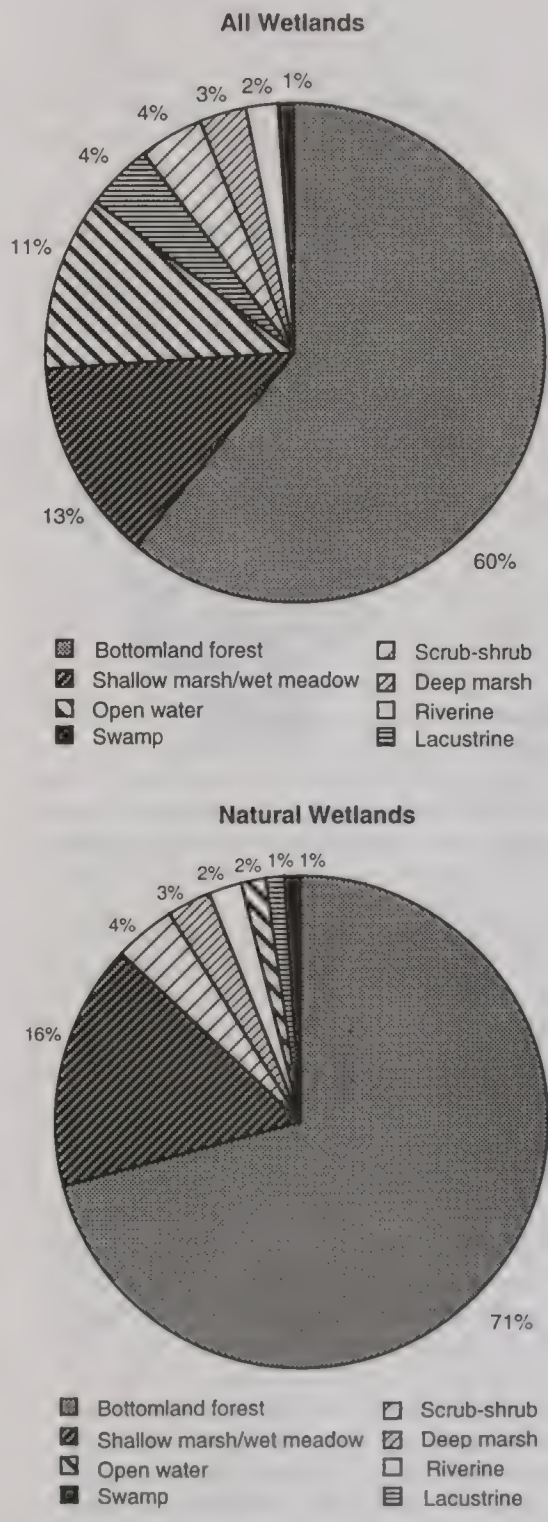

Figure 6. Amounts of various types of wetlands as a percentage of all wetlands (top) and of natural wetlands (bottom) for Illinois based on Illinois Wetlands Inventory data, 1980 to 1987.

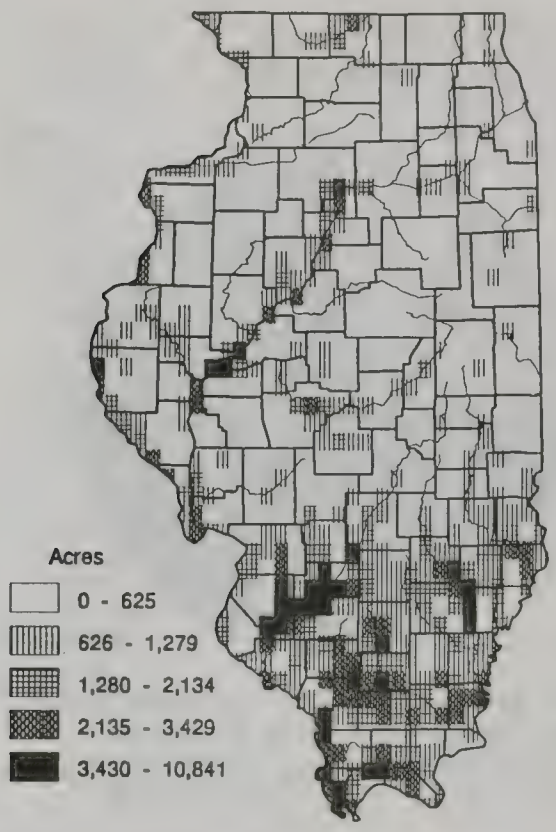

Figure 7. Distribution of forested wetlands by 7.5-minute quadrangle (1980–1987). Source: Suloway et al. 1992.

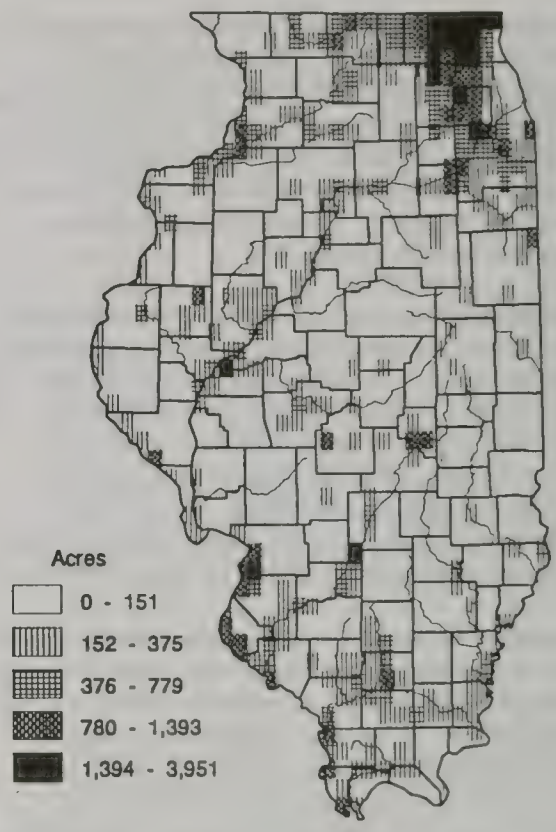

Figure 8. Distribution of emergent wetlands by 7.5-minute quadrangle (1980–1987). Source: Suloway et al. 1992.

(where standing water is present, or the soil is saturated, on a semipermanent to permanent basis during the growing season) (Table 2). Shallow marshes and wet meadows were once common in the state. They are often part of larger wetland complexes, such as the edge of ponds and lakes. The IWI identified 162,913 acres (65,957 ha) (146,873 natural acres; 59,463 ha) of shallow marshes and wet meadow, which represent 81% of emergent wetlands and 13% of all wetland acreage (Table 3). This habitat type has had 44% of its acreage affected by drainage and farming. The largest distribution of this wetland type is in northeastern Illinois, with smaller areas of concentration scattered throughout the state.

In the 1980s, 3% of the state's wetland acreage was deep marsh habitat. There were 38,708 acres (15,671 ha) (25,305 natural acres; 10,245 ha) of this habitat in Illinois (Table 3). The largest concentration of deep marsh occurs in northeastern Illinois, with small areas of concentration at the mouth of the Sangamon River and at Carlyle Lake (Figure 8).

Open Water Wetlands. Small and shallow [area < 20 acres (8.1 ha) and depth < 6.6 ft (2 m)] open water areas are classified as open water wetlands in the IWI. Natural ponds, farm ponds, borrow pits, small reservoirs, and open water areas that occur within a marsh or swamp are included in this category. Ponds are classified as wetlands because they support typical moist-soil and water-loving plants. In addition, they are often surrounded by marshes or wet forests. Soils may be organic or mineral. Typical plants found in natural ponds include arrowhead, spadderdock (pond lily), and water lily.

In the 1980s, open water wetlands accounted for 11% of wetlands, with 143,345 acres (58,034 ha); 89% of this wetland type has been modified or altered by dikes, impoundments, or excavation (Table 3, Figure 6). Three regions have the greatest concentration of open water wetland habitat: the northeast and southwest areas of the state and Fulton County.

Scrub-Shrub Wetlands. This type is characterized by woody vegetation less than 20 feet (6 m) tall. Scrub-shrub wetlands can be a successional stage in the transition of an emergent wetland to forest, or it may represent a semi-stable community such as the shrub bogs of northeastern Illinois. About 4% of the state's

wetlands are scrub-shrub. Of the 50,366 acres (20,391 ha) (38,401 natural acres; 15,547 ha) of this habitat, most is found along the Illinois River, northeastern Illinois, or scattered throughout southern Illinois (Table 3).

Lacustrine Wetlands

Lacustrine wetlands account for 4.4% of the existing wetlands in the state (Figure 6). These wetlands are situated in a topographic depression or are dammed river channels; they are shallow (< 6.6 feet deep), are larger than 20 acres (8.1 ha), and have less than 30% vegetative cover. Permanently flooded natural or artificial lakes and reservoirs are in this group. Lacustrine wetlands are divided into three types: shallow lake, shore, or emergent wetlands. Most of the lacustrine wetlands are shallow lake habitat created by dikes, impoundments, or excavation. The 51,868 acres (20,999 ha) (9,354 natural acres; 3,787 ha) of shallow lake habitat is limited to a very small area of the state, mostly along the Illinois River and in northeastern Illinois in Lake and McHenry counties (Table 3). Lake shore wetlands, found along the edges of large rivers and the shores of wave-affected lakes, account for less than 3,000 acres (1,215 ha) (422 natural acres; 171 ha), mainly at Carlyle Lake. Lacustrine wetlands may have a zone of emergent vegetation extending from the shore to a depth of 6.6 foot (2 m). The total area of littoral emergent wetlands in the mid-1980s was 772 acres (313 ha) (531 natural acres; 215 ha) (Table 3). This habitat occurs mostly in the Big Muddy Basin.

Riverine Wetlands

Riverine wetlands are shallow (< 6.6 feet) waters contained within a channel where water is usually flowing; they are not dominated by vegetation or impounded. Riverine wetlands account for 2.3% of the wetlands in the state and occupy a total area of 29,358 acres (11,886 ha) (19,302 natural acres; 7,815 ha) (Figure 6, Table 3). Shallow water riverine wetlands are concentrated in the Illinois River basin, the west-central portion, and southern quarter of the state. Most of the riverine wetlands are intermittent streams—that is, water flows for only part of the year.

Rare Wetland Communities

The preceding discussion of types of wetlands was based on the classification system devised for NWI (Cowardin et al. 1979) and subsequently modified for the IWI. The NWI/IWI classification is not designed to separately identify important types of wetlands known as bogs, fens, seeps, springs, and pannes. Because these types are generally unique or rare in Illinois, they were well-documented by the Illinois Natural Areas Inventory (INAI). The vegetational communities described in the following section are classified according to the INAI (White 1978), with minor modifications when describing endangered species habitats.

Certain wetland community types have never been abundant on a statewide basis, although some may have been locally common in certain regions of Illinois. These rare communities include seeps, pannes, and two peatland types: bogs and fens. These wetlands have been further reduced by land development, and most remnants have become disturbed since early settlement. Relatively undisturbed remnants identified by the INAI are now extraordinarily rare in Illinois; less than 350 acres (142 ha) of each type of rare wetland is considered yo be of high quality (Figure 9).

Peatlands. Peatlands are wetlands with organic (rather than mineral) soils developed from partially decomposed plant material. Organic matter accumulates when plant growth exceeds decomposition. Factors that retard decomposition, such as cold temperature and anaerobic (saturated) conditions, contribute to peat accumulation (Johnson 1985, Crum 1988); thus, peatlands in the Midwest are restricted to the cooler northernmost region extending south to the northern half of Illinois, where most have developed in glacial pothole depressions. Peat in Illinois is derived from three principal sources: sedges, mosses (especially *Sphagnum* spp.), and limnic origins.

The type of peatland is controlled by a complex of climatic, hydrologic, topographic, and geologic factors (Johnson 1985). Two of the three principal types of peatlands occur in Illinois.

1. Minerotrophic peatlands are characterized by a predominantly sedge peat saturated with mineral-rich (alkaline in Illinois), flowing groundwater; this includes all fens in Illinois.
2. Oligotrophic peatlands are characterized by sedge and/or moss peat saturated with ground and rain water, but acidified by a developing *Sphagnum* mat. These include the level bogs of northeastern Illinois. Some peatlands mostly lacking a *Sphagnum* mat but not strongly minerotrophic occur in Illinois and can be considered fens (Taft and Solecki 1990).
3. Ombrotrophic peatlands do not occur in Illinois. Ombrotrophic peatlands are rain-fed and receive minerals solely from the atmosphere. These include raised bogs and are the most nutrient poor and most acidic of all peatlands.

Bog and fen peatland communities have not always been considered distinct, but these wetlands support such unique biota that separate classification for scientific and conservation purposes is desirable.

All bogs in Illinois developed from fens in glacial pothole depressions (Sheviak 1974) where hydrological outlets were limited and acids released from certain *Sphagnum* mosses have affected the local soil and water chemistry (Taft and Solecki 1990). Fens are primarily concentrated in northeastern Illinois (Figure 10), where the calcareous nature of the glacial till often readily mineralizes the groundwater with an alkaline reaction. When groundwater meets a resistent stratum, such as calcareous bedrock in northeastern Illinois, it flows laterally until it issues through the margin of a pothole depression, edge of a moraine, or locally from the sides of river valleys often as diffuse seeps and spring runs (Figure 11). Permanently cold seepage results in cool anaerobic soil conditions, incomplete decomposition, and consequently an accumulation of peat.

The precise determination of the total area of original peatland in Illinois is difficult, and distinguishing original bog from fen acreage is not possible. Some estimates can be made from early soil surveys. According to Soper and Osbon (1922), several Illinois counties had peat deposits (Figure 12). Although, according to early soil surveys, Lake County supported the most peatland (and muck) in Illinois, the largest single peat deposit was in the former Cattail Slough in Whiteside County, a 1-mile (1.6-km) wide valley extending about 12 miles (19.2 km), with peat measured to a depth of 30 feet (9.7 m) (Soper and Osbon 1922). Peat was being mined in this deposit for fuel long before 1877 (Bent 1877).

Early soil surveys included muck soils (organic sediments—plant materials well decomposed and indistinguishable) in their total estimates of peat for each county, probably because muck and peat deposits often occurred within the same wetland complex. This incorporation resulted in an overestimate of peat acreage. Conversely, countless small pothole depressions supporting peat occurred throughout the northern third of Illinois and would not have been included in these estimates because individually they were too small; collectively, however, they composed substantial acreage. Furthermore, modern soil surveys are often at least 20 years old and no longer accurately reflect the

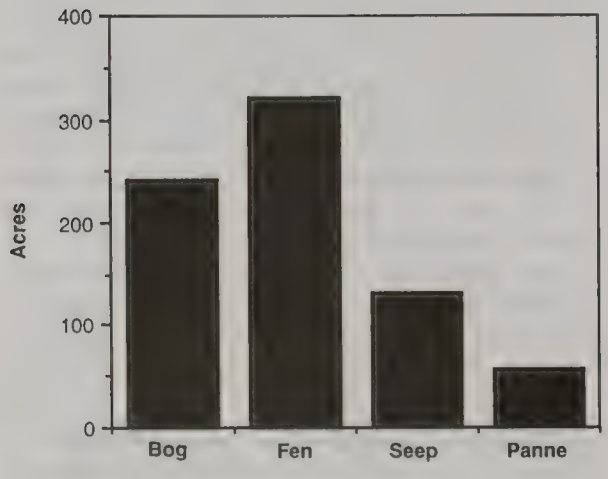

Figure 9. Amounts of high-quality rare wetland types in Illinois.

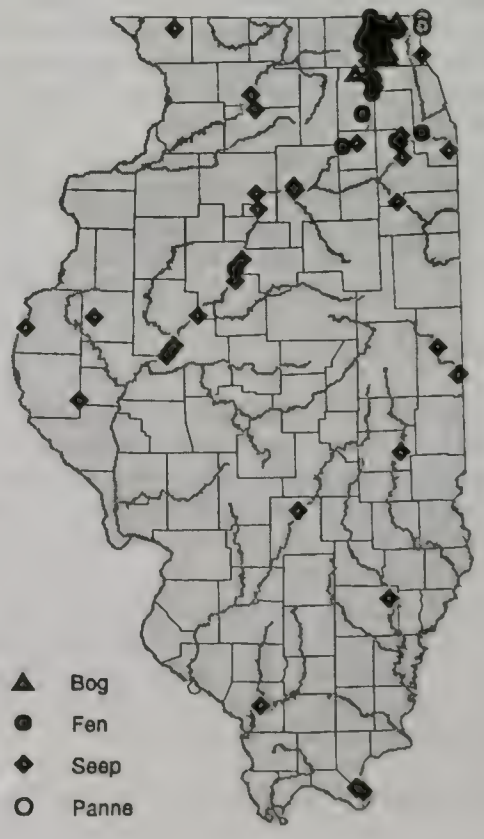

Figure 10. Locations of fens, bogs, seeps, and pannes identified by the Illinois Natural Areas Inventory as significant and relatively undisturbed remnants. Source: White 1978, Illinois Natural Areas Inventory digital database.

total area of peatland soils. For this report, the standard measure of the total area of high-quality, relatively undisturbed bogs and fens in the state is based on the INAI (White 1978), and these acreage data are now 15 years old. Despite the difficulty of determining precisely the total area of original peatland in Illinois, the data available, when compared with the results of the INAI, reveal a clear trend suggesting a substantial loss of peatlands (Table 4).

Factors leading to the destruction and degradation of peatlands include drainage and subsequent lowering of the water table, cultivation, peat harvesting, grazing by domestic stock, and invasion by exotic species. As a result of oxidation, once a peatland is drained or the hydrology is altered, the peat decomposes, forming muck when wet (Willman and Frye 1970) or humus when drier (Hester and Lamar 1969). For a time, Illinois ranked highly among all states in the amount of peat harvested, second in 1967 and third in 1973 (Samson and Bhagwat 1985). These are surprising statistics considering several other northern states support far greater acreages of peatland. Historically, peat was mined for fuel in Illinois; in more recent years it has been harvested primarily for horticultural use. Six major areas of peat production were located in Illinois during the late 1960s (Figure 12) (Hester and Lamar 1969). Humus was mined from at least one site, and peat and/or humus was mined at two Cook County sites (Willman 1971).

Both bogs (Figure 13) and fens support a unique flora adapted to the acidic or alkaline conditions present. Both of these peatland types in Illinois have acted as refugia for plants with current distributions principally north of Illinois. These northern species became established locally during and following the close of the last (Wisconsinan) glacial episode. Many of these plants are listed as threatened or endangered species in Illinois (Herkert 1991). Fens and bogs each support a total of 34 plant species listed as threatened or endangered (Figure 14), more than any other wetland community type in Illinois. For example, within a single wetland complex at Gavin Bog and Prairie Nature Preserve in Lake County, nine threatened and endangered plant species are known to be extant from the bog communities and an additional six threatened and endangered species are present in associated wetland and prairie communities (Table 5). As many as 22 species of threatened and endangered plant species have been reported from Volo Bog (Figure 13) in Lake County (White 1978). However, not all of these species are known to be extant at Volo Bog. In addition to supporting numerous rare species, bog and fen remnants in Illinois show considerable floristic variance, with the greatest index of floristic similarity (i.e., how

Figure 11. Calcareous seepage forming spring run at Bluff City Fen in Cook County.

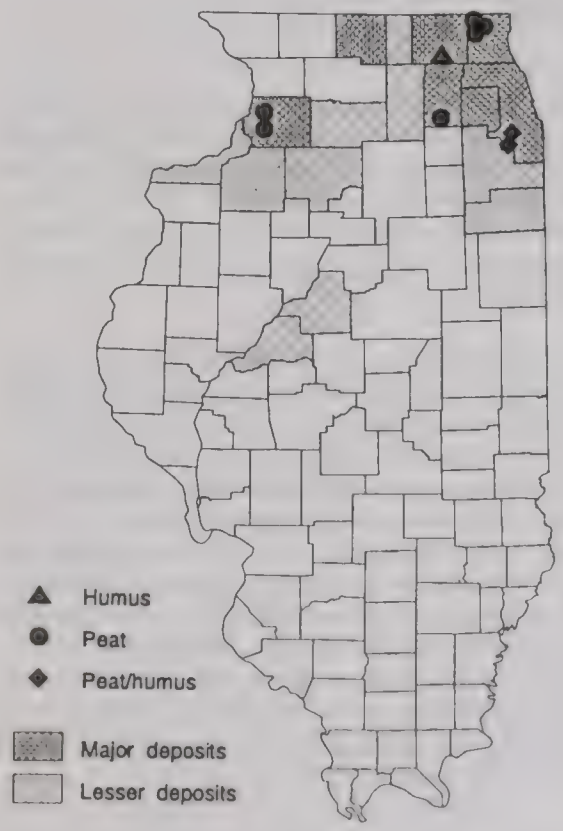

Figure 12. Illinois counties with known peat deposits (shading) and locations of principal peat and humus mining (symbols). Source: Soper and Osbon 1922, Hester and Lamar 1969, and Willman 1971.

Table 4. Estimates of historical (Soper and Osbon 1922) and contemporary (Soil Conservation Service 1993) acres of peat and muck in Illinois compared with the results of the Illinois Natural Areas Inventory (INAI) (White 1978).

County	Historical peat and muck	1993 soil survey Muck	1993 soil survey Peat	INAI Grades A and B
Boone	NA[a]	3,557	0	0
Cook/DuPage	NA	10,341	0	22
DuPage	4,186	—[b]	0	0
Kane	9,299	9,639	0	23
Kankakee	1,747	1,707	0	0
Lake	24,384	17,122	465	286
Lee	NA	999	0	0
Mason	NA	1,046	0	0
McHenry	NA	20,485	1,760	226
Tazewell	1,344	790	0	0
Whiteside	2,580[c]	3,455	0	0
Will	NA	2,385	0	0
Winnebago	1,427	3,557	0	0
Woodford	NA	NA	0	5
Statewide	42,387	98,331	2,225	562

[a] Not available.
[b] See Cook/Dupage
[c] Peat acres only.

many species any two sites share) among four Illinois peatlands (two bogs and two fens) and one Indiana bog being 45% (Table 6). These data suggest that any one of the sites is not representative of other sites and that protection of one or two sites is not adequate to preserve the diversity originally established in Illinois peatlands.

Pannes. Pannes are interdunal swales restricted to the Lake Michigan lakeshore region where undeveloped portions remain (Figure 10), primarily Illinois Beach State Park and Illinois Dunes North in Lake County. The calcareous nature of the sand, derived from the dolomitic bedrock of the region (Willman 1971), creates an alkaline reaction in the seasonal ponds, and several species are specifically adapted to this habitat. A progression of species can be observed to develop throughout the growing season as the pond level diminishes, exposing pond margins. Several unusual species, including carnivorous bladderworts and species from the Atlantic coast, are found in or are restricted to pannes in Illinois.

Seeps. Seeps are wetland communities that are formed where groundwater flows to the surface through porous substrates such as gravel or sand (Ebinger 1978). These communities are similar to springs; the main difference is the manner in which water flows out of the ground.

Figure 13. Open water zone of Volo Bog Nature Preserve in Lake County. Volo Bog is the only Illinois bog retaining an open-water zone; all other Illinois bogs are at a more advanced stage of lakefill.

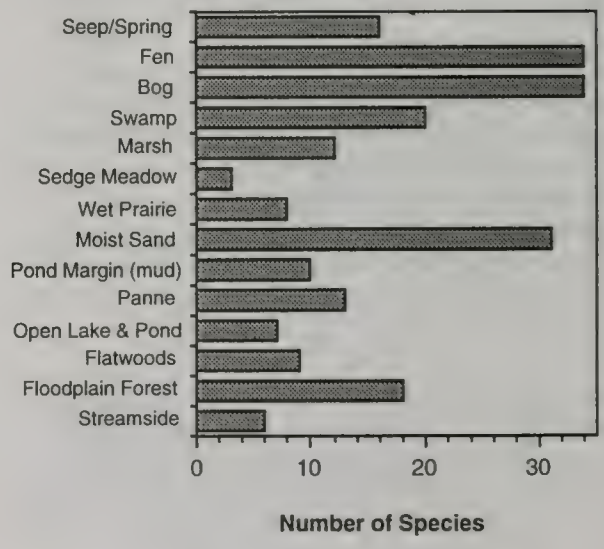

Figure 14. Number of threatened and endangered species found in various types of wetlands in Illinois.

In a seep, water generally flows out diffusely, occasionally collecting into concentrated spring runs, whereas groundwater in a spring emerges in a concentrated form, often from a definite opening. The pH of the groundwater that emerges at a seep varies throughout the state, influenced by the type of substrate through which the water flows. The groundwater of most seeps is circumneutral or slightly calcareous (rich in calcium carbonates); some seeps are so calcareous that tufa deposits (precipitates from the highly mineralized groundwater) collect where the water emerges. Acid seeps are rare in Illinois. One acid seep occurs in

Castle Rock State Park (Ogle County), where the groundwater is mineralized by the St. Peter sandstone. Another is found in the Cretaceous Hills Nature Preserve (Pope County), where groundwater is mineralized by Cretaceous-aged gravel deposits (White 1978). Seeps are often found in close association with other wetland communities, and boundary distinctions may not be very obvious. Calcareous seeps may be adjacent to some fen communities, and water from some seeps may collect in low areas downslope from the seep and form extensive marshes.

In 1978, the Illinois Natural Areas Inventory identified approximately 30 high-quality seeps throughout the state that retained their presettlement condition (Figure 10) (White 1978). The total seep acreage identified by this inventory was 124.2 acres (50.3 ha), with 9.7 acres (3.9 ha) of sand seep communities, 6.0 acres (2.4 ha) of acid seep communities, 14.5 acres (5.9 ha) of calcareous seep communities, and 94.0 acres (38.0 ha) of seep communities with nearly neutral pH conditions. In Illinois, seeps are generally found in stream valleys, along the lower slopes of terraces and ravines. The majority of the inventoried seeps were found in the Fox, Des Plaines, Illinois, and Vermilion river valleys, with scattered locations along the Rock, Kankakee, Kaskaskia, Embarass, Little Wabash, and Big Muddy rivers (Figure 10) (White 1978). In addition to these sites, many smaller or lower quality seeps are found in Illinois. A recent botanical survey along the Middle Fork of the Vermilion River in east-central Illinois identified nine additional seeps (M. Morris, Illinois Natural History Survey, personal communication).

In addition to being somewhat mineralized, the groundwater that seeps to the surface is generally cooler than surface water. These characteristics create unique conditions for the development of uncommon plant communities. Often, plants typically known from more northern locations are found within seeps, isolated from their normal ranges. Plants often found in seep communities include marsh marigold, skunk cabbage, grass-of-Parnassus, black ash, willows, jewel weed, joe-pye-weeds, and many sedges and rushes.

Table 5. Threatened (T) and endangered (E) plants found at Gavin Bog and Prairie Nature Preserve in Lake County (Taft and Solecki 1990).

Common name	Scientific name	Status in Illinois
Bearded wheat grass	*Agropyron subsecundum*	E
Brownish sedge	*Carex brunnescens*	E
Awned sedge	*Carex atherodes*	E
Three-seeded sedge	*Carex trisperma*	E
Leatherleaf	*Chamaedaphne calyculata*	T
White lady's slipper	*Cypripedium candidum*	E
Small yellow lady's slipper	*Cypripedium parviflorum*	E
Rusty cotton grass	*Eriophorum virginicum*	E
Tamarack	*Larix laricina*	T
Small sundrops	*Oenothera perennis*	E
Northern gooseberry	*Ribes hirtellum*	E
Star-flower	*Trientalis borealis*	T
Highbush blueberry	*Vaccinium corymbosum*	E
Small cranberry	*Vaccinium oxycoccos*	E
Marsh speedwell	*Veronica scutellata*	T

Table 6. Sorensen's similarity indices calculated for four Lake County, Illinois, peatlands (two bogs and two fens) and one Indiana bog (Pinhook) (Taft and Solecki 1990). Marsh communities were included in the comparisons. Numbers represent the percentage of floristic elements in common.

	Pinhook	Wauconda	Barrington	Volo
Gavin	39	39	31	41
Volo	36	45	35	
Barrington	32	33		
Wauconda	30			

PRESETTLEMENT WETLANDS

Amount

An estimate of the quantity and distribution of presettlement wetlands in Illinois was derived from soil survey data. Soils that develop under hydric conditions, regardless of their present use, retain many properties diagnostic of wetland soils. Hydric soils have been used as a means to approximate original wetland acreage (Dahl 1990). Hydric soils have been described as being saturated, flooded, or ponded for a sufficient period of time during the growing season to develop anaerobic conditions in the upper part (U.S. Department of Agriculture 1985, Pierce 1989, Wilen 1990). A national list of hydric soils was developed by the National Wetlands Inventory and the Soil Conservation Service (SCS) (U.S. Department of Agriculture 1987). The substrates of deepwater habitats are considered nonsoil because the water is too deep for the growth of emergent vegetation (U.S. Department of Agriculture 1975). Combining soil information with other available data provided a reasonable estimation of the amount and distribution of presettlement wetlands in Illinois.

Based on the analyses of soil types, a conservative estimate is that 8,261,600 acres (3,343,424 ha) of wetlands existed in Illinois before settlement by

Europeans (Havera 1985); this area represents 23% of the surface area of the state. The estimated amount of wetland soils identifying presettlement wetlands is presented for each county in Figure 15 (see also Appendix 2). This estimated hydric soil acreage is shown as a percentage of wetland soils in each county based on a randomized 2% sampling of Illinois soils (Runge et al. 1969).

A more recent soil survey of hydric soil acreage is based on modern soil survey data in the SCS database (J. Doll, Soil Conservation Service, personal communication) (Figure 16; see Appendix 2). Soil mapping, editing, and data preparation are continuing in 24 counties. Thus, the modern soil survey data are not available for the entire state. A preliminary estimate of presettlement wetlands based upon the modern soil survey data in 78 of the 102 Illinois counties is 9,412,659 acres (3,809,251 ha), a value higher than that estimated for the amount of presettlement wetlands in the entire state in the initial determination of hydric acres. Intensive urbanization occurred in Illinois, especially in the metropolitan Chicago area, before modern soil data were amassed. Consequently, estimates of modern hydric soil acreage, or presettlement wetland data, for these areas will be conservative.

A recent inventory of wetlands in Illinois (Suloway et al. 1992) revealed that approximately 917,765 acres (371,414 ha) of natural wetlands remained in Illinois (Table 3, Figure 17); only about 6,000 acres (2,429 ha) were high quality and undisturbed (White 1978). Using the modern soil survey incomplete estimate of 9.4 million acres (3.8 million ha) of presettlement wetlands, Illinois has lost 90.2% of its original wetlands (Figure 18). Many of the original wetlands were lost in the northern two-thirds of the state, particularly east-central Illinois (Figure 19). From presettlement times to the 1980s, natural wetlands in Illinois have declined from at least 23% (and probably more than 26%, using the incomplete modern soil survey) of the state's surface area to only about 2.6% (Figure 20).

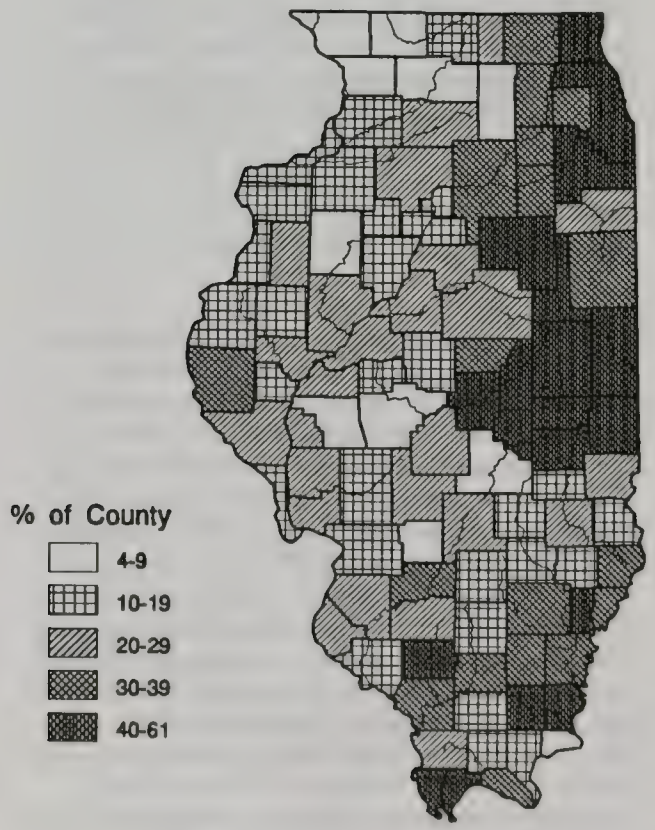

Figure 15. Percentage of each Illinois county before settlement that was wetlands, based upon a 2% soil survey. Sources: Runge 1969, Havera 1985.

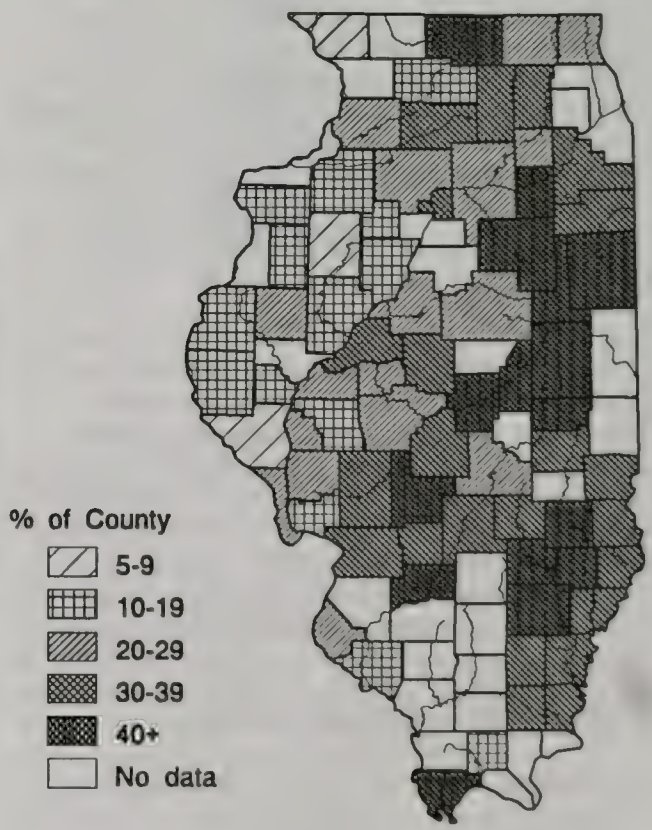

Figure 16. Percentage of each county before settlement that was wetlands, based upon Soil Conservation Service soil surveys currently in progress.

Distribution

The types and approximate distribution of presettlement wetlands in Illinois are depicted in Figure 21. This estimation of the distribution of presettlement wetlands in Illinois was based predominantly on maps of soil associations. Maps of soil associations were coupled with data on the amount of soil types formed under wetland conditions, maps of organized drainage and levee districts, and historical wetland information to derive an estimate of the approximate distribution of presettlement wetlands in Illinois. The types of presettlement wetlands (i.e., wet prairie, bottomland hardwood, deep marsh, etc.) were determined from historical accounts, maps of forests, and characteristics of soils in the region. The types of presettlement wetlands are generalized designations, which indicate the dominant (but not necessarily the only) wetland type in the area. The distribution of the remaining natural wetlands in Illinois is only a glimmer of the original marshes, shallow lakes, swamps, and wet meadows (Figures 4, 16, 17, 21).

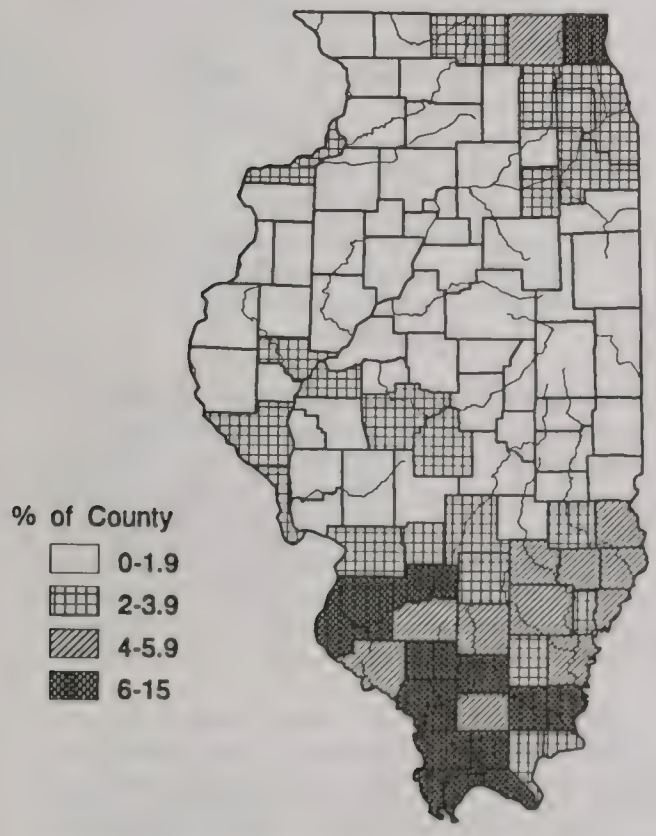

Figure 17. Percentage of each county that was natural wetlands in the 1980s. Source: Suloway et al. 1992.

WETLAND PLANTS IN ILLINOIS

Plants are important in the determination of wetlands. Unlike wetland hydrology, which may only be visible for part of the year, wetland plants are evident for a much longer time. Water depth is perhaps the most influential physical factor in determining the kinds of plants that occupy a site. Because more plant species are adapted to moist-soil conditions than to open water (strictly aquatic conditions), the shallower the water, the greater the potential diversity of species.

Wetlands support a variety of plant life. A total of 108 of the 172 families of vascular plants that occur spontaneously in Illinois contain species that thrive in aquatic or moist-soil habitats. Vascular plants are those with both xylem (supporting and water-conducting tissue) and phloem (food-conducting tissue). Some floating-leaf plants such as water lilies are secondarily vessel-less, indicating a terrestrial origin. Such species are rooted deep below the surface of the water and send up broad, flat leaves that rest on the surface, where photosynthesis occurs. Nutrients move between the leaves and the underwater roots via imperforate tracheids in the plants' long, slender, flexible stems.

Free-floating plants such as duckweeds are not rooted but remain on the surface of the water, usually with their roots dangling. By contrast, emergent plants,

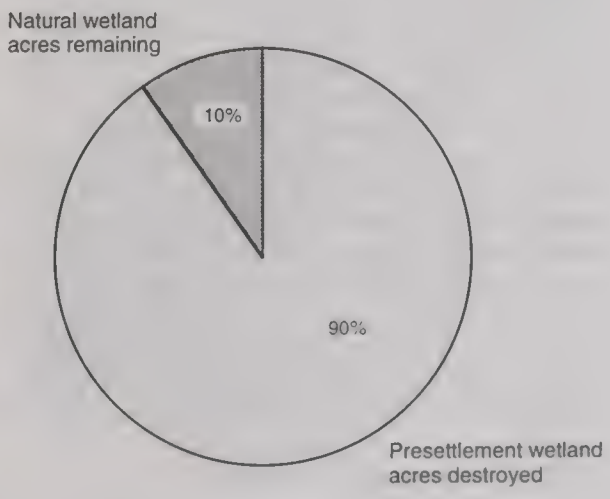

Figure 18. Amount of natural wetlands remaining in the 1980s relative to the amount of presettlement wetlands that have been destroyed. Only about 6,000 acres of high-quality, undisturbed wetlands remain (about 0.05% of the presettlement wetland acreage).

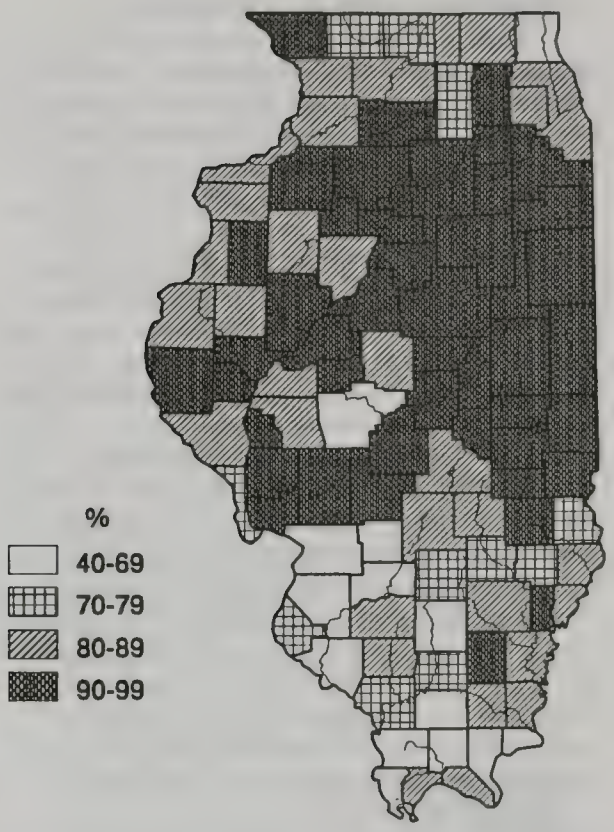

Figure 19. Percentage of presettlement wetlands lost in each county by the 1980s.

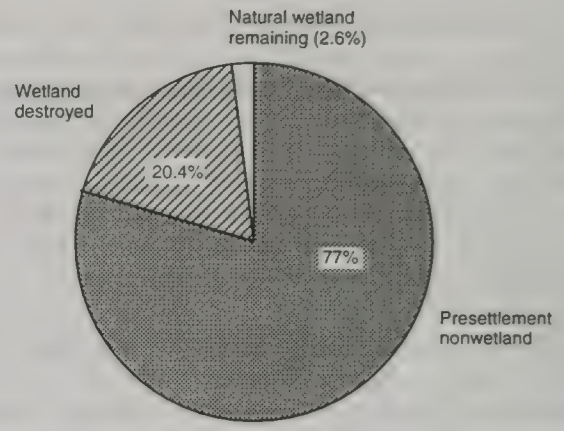

Figure 20. Percentage of presettlement Illinois that was nonwetland (77%) and wetland (23%) and percentage of the land that remains wetland (2.6%).

including cattails, arrowheads, and bulrushes, are amphibious; that is, they grow with their roots in wet soil for all or part of the year and send up leaves that stand erect above the surface of the water. Submerged plants like pondweeds are also rooted in the soil, but their stems and leaves remain entirely underwater. Other plant types that occupy the drier portions of wetlands include moist-soil plants (sedges), moist-soil shrubs (buttonbush and red osier dogwood), and moist-forest species (tamarack, bald cypress, and silver maple). Some wetlands contain all of these vegetation types, but others have only one or two. Along with water chemistry and hydrology, differences in vegetation help to determine the presence of a wetland and also to distinguish among the various types of wetlands.

Groups (Taxonomic and Habit)

The species identified in this document as wetland plants are that part of the Illinois vascular flora recognized in the National List of Plant Species that Occur in Wetlands (Reed 1988) and include all species ranked FAC+ and wetter. Botanical nomenclature approximates that of Mohlenbrock (1986). For this report, numerical values used as wetness coefficients have been substituted for the regulatory ranks assigned to each wetland species:

–5 = Obligate wetland species (OBL)
–4 = Facultative wetland species (FACW+)
–3 = Facultative wetland species (FACW)
–2 = Facultative wetland species (FACW-)
–1 = Facultative species (FAC+)
0 = Facultative species (FAC)
1 = Facultative species (FAC-)
2 = Facultative upland species (FACU+)
3 = Facultative upland species (FACU)
4 = Facultative upland species (FACU-)
5 = Upland species (UPL)

These wetland ranks were determined by a nationwide survey of botanists and ecologists and reflect the degree of certainty that a given species will be found in a regulatory wetland. For example, an obligate wetland species (OBL) will be found in a wetland in roughly 99 to 100% of instances. This occurrence diminishes to a mean of 50% for facultative species (FAC). For upland species (UPL), there is a 99 to 100% likelihood that the taxon will be found in an upland habitat (Reed 1988).

A qualitative analysis of the Illinois wetland flora revealed several useful perspectives. Most wetland plant species are classified under a broadly defined habit class called forbs (Figure 22). This definition excludes the graminoid monocots such as sedges and grasses but includes most other herbaceous species except vines and ferns. Sedges, species in many wetland community types, rank as the second most important habit group (Figure 22).

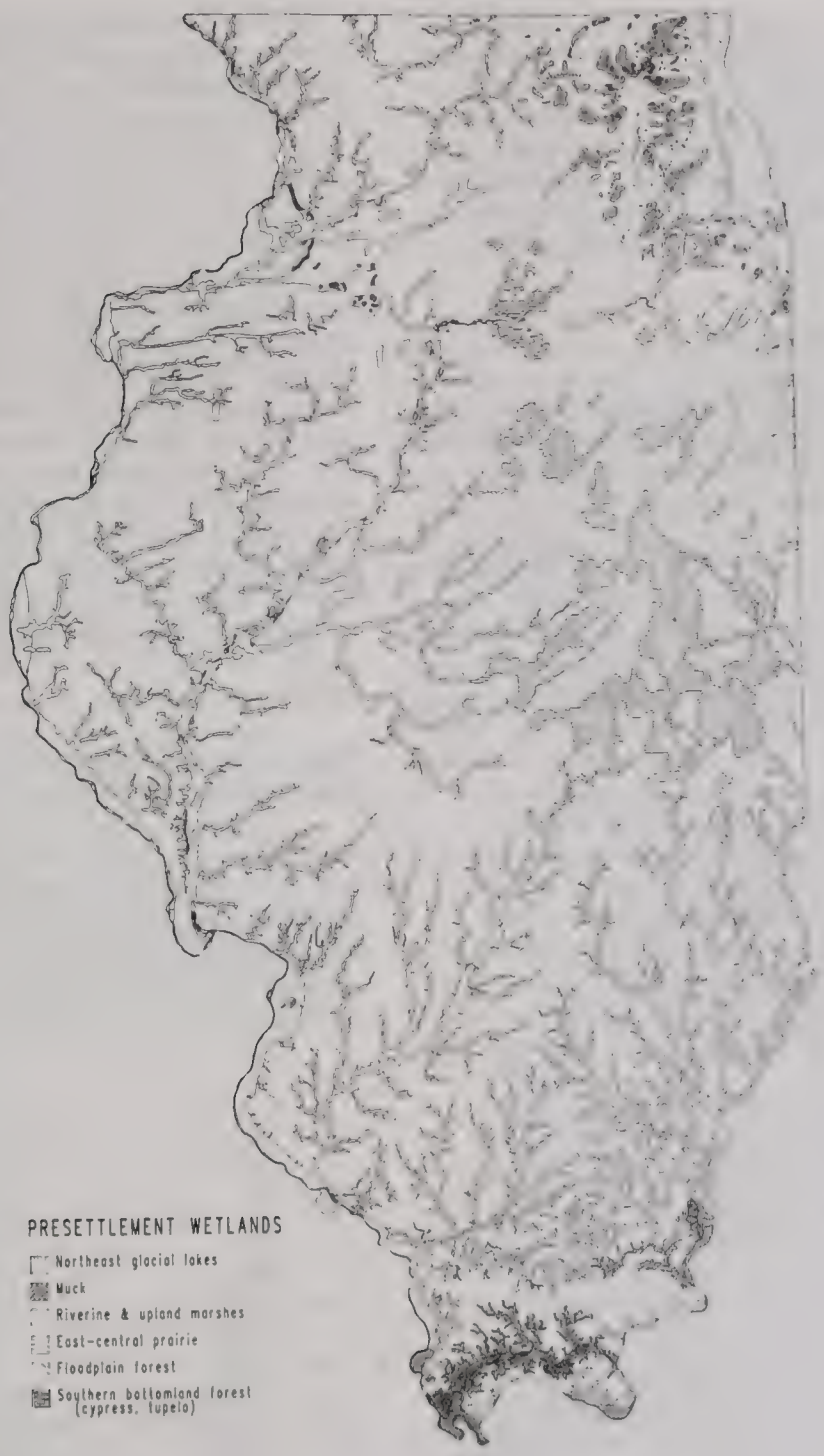

Figure 21. Approximation of the types and distribution of presettlement wetlands in Illinois. This estimate of presettlement wetlands was based principally on maps of soil associations with supportive data from maps of drainage and levee districts, maps of forests, and historical wetland information. Source: Havera 1985.

A taxonomic breakdown of the wetland vascular flora indicates that the sedge family (Cyperaceae), with 163 species, is the most species-rich family, followed by the grass family (Poaceae), with 81 species (Figure 23). Other important families include the sunflower (Asteraceae), orchid (Orchidaceae), mint (Lamiaceae), and rose (Rosaceae) families. The most species-rich subfamily rank is the sedge genus *Carex*, with 90 wetland species.

Distribution and Diversity

Distribution data for wetland plant species were taken from the Illinois Plant Information Network (ILPIN), a database on the flora of Illinois maintained at the Illinois Natural History Survey (Iverson 1992).

An assessment of native wetland vascular plant species known to have occurred in each Illinois county revealed regions of wetland species diversity (Figure 24). Biotic and abiotic elements that contributed to the number of native wetland vascular plants that occurred in each county include county size, diversity of original wetland community types, and, to an extent, intensity of botanical exploration. When all vascular plant species known to occur spontaneously in Illinois, including native and exotic taxa, were considered, the Illinois wetland flora of about 952 species (including varieties) constituted about 32% of the total flora (Figure 25). However, when only species native to Illinois were considered, wetland species identified by the conservative definition used in this report constituted about 42% of the total vascular flora (Figure 26).

Abundance

The locations of high-quality, relatively undisturbed wetland communities identified during the INAI (White 1978) were concentrated locally along the Fox, Des Plaines, and Kankakee rivers in northeastern Illinois, along the middle Illinois River valley, and in the Gulf Coastal Plain of extreme southern Illinois (Figure 27). The presettlement abundance of natural wetland areas in Illinois (Figure 18) indicates a profound loss of habitat integrity. Of the 9.4 million acres (3.8 million ha) (Appendix 2) (Soil Conservation Service 1993) of wetlands estimated to exist at one time in Illinois, only 6,000 acres (2,429 ha; 0.05% of the original total) persist in an undisturbed condition (White 1978). These undisturbed, high-quality wetlands are our most reliable qualitative indicator of the original structure and composition of the various wetland communities in Illinois.

A total of 1,287 vascular plant species in Illinois are obligate upland species (43%). Obligate wetland species, the next largest single regulatory group, constitute 511 species (17%) (Figure 28). The remaining 1,161 taxa (39% of the total flora) have wetness coefficients from –4 to +4 (facultative wetland species [FACW+] to facultative upland species [FACU–]). Most facultative species fall within a range of likelihood between 50 and 99% of being found in wetland (wetness coefficients –4 to –1) or upland (wetness coefficients +4 to +1) habitats. The 206 species ranked with the coefficient 0 (facultative species) are estimated to have a likelihood between 33 and 50% of being found in a wetland. These taxa were not included in our conservative accounting of the wetland species of Illinois. This accounting indicates that about 54% of the wetland flora in Illinois are almost exclusively found in wetland communities (that is, they have a wetness coefficient of –5). Conversely, about 46% of the wetland species in Illinois (i.e., those with wetness coeffients of –4 to –1) can be found, at least occasionally, in upland habitats.

Threatened and Endangered Species, Extinctions, and Extirpations

Twenty-six percent of the 109 federally listed threatened and endangered plant species in the United States are wetland-dependent or wetland-related (Feierabend and Zelazny 1987). Approximately 30% of the 2,500 plants in need of federal protection depend upon wetlands (Feierabend and Zelazny 1987). About 17%

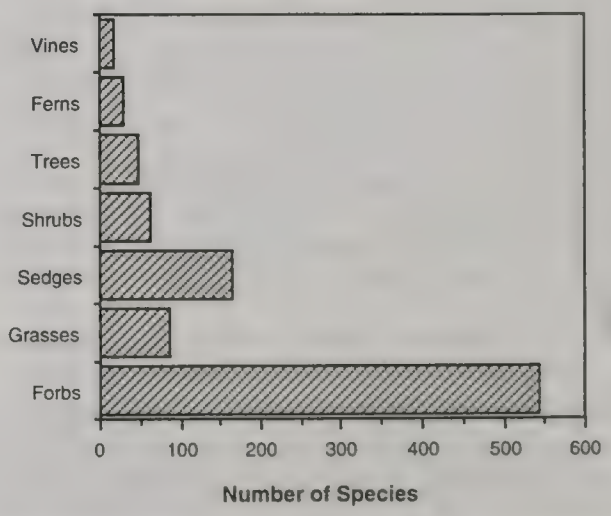

Figure 22. Number of wetland plant species per growth habit group in Illinois.

of the native vascular flora (wetland and upland) in Illinois (Figure 29) and 18.6% of the native wetland flora (Figure 30) are listed as threatened or endangered (Bowles et al. 1991). Illustrating the number of threatened and endangered wetland plant species for each county revealed a primary concentration of rare wetland species in northeastern Illinois and secondary concentration in far southern Illinois (Figure 31). Depicting the number of threatened and endangered wetland species extirpated in each county also revealed a concentration in the heavily developed northeastern counties (Herkert 1991) (Figure 32). (Extirpated means a species was formerly found in a given region but is no longer believed to occur there; extinct means a species no longer exists anywhere.) High rates of extirpations of threatened and endangered wetland species were also present in the Illinois River counties of Peoria, Tazewell, Cass, and adjacent Menard and in the southwestern Illinois counties of St. Clair, Alexander, Jackson, Union, and Pulaski (Figure 32).

The northeastern counties of Lake, Cook, and McHenry supported the greatest number of rare wetland plant species in Illinois (Figures 31, 32). Lake County historically hosted the greatest number of wetland plant species that are listed as threatened and endangered, with a total of 80; currently, Lake County, with 66 threatened and endangered wetland species, still ranks highest of all Illinois counties. Cook County formerly ranked second among Illinois counties, with a total of 74 wetland plant species that are listed as threatened and endangered today. However, the extirpation of 36 of these species placed Cook behind McHenry County, which still supported 41 threatened and endangered wetland species though it lost 16. Some counties, such as Peoria, Tazewell, Kankakee, St. Clair, Menard, Hancock, Alexander, Winnebago, and Ogle, have had exceptionally high rates of extirpations of threatened and endangered wetland plant species.

Comparing the number of county occurrences of threatened and endangered wetland plant species with the number of county extirpations from 1981 (Sheviak 1981) and 1991 (Herkert 1991) appears to indicate a measure of recovery (Figure 33). However, the total number actually demonstrates increased knowledge of the distribution of rare wetland plants throughout Illinois as a result of additional field work (Bowles et al. 1991). Although we may never have a complete record of the distribution and frequency patterns of all rare wetland species, some of which are cryptic and may not be present during every growing season,

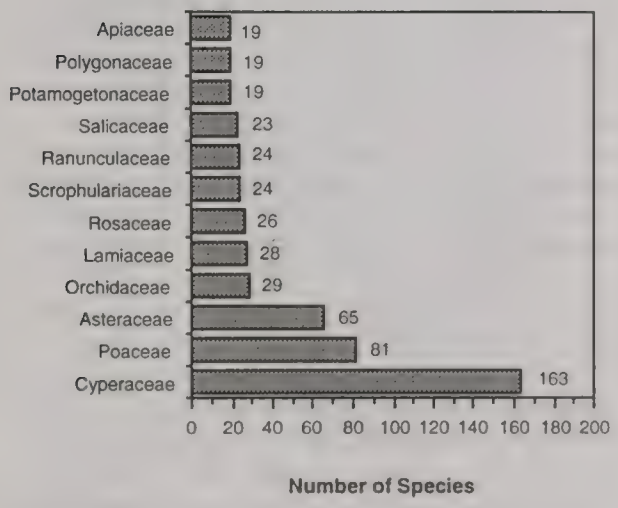

Figure 23. A ranking of the vascular plant families with the most wetland species in Illinois.

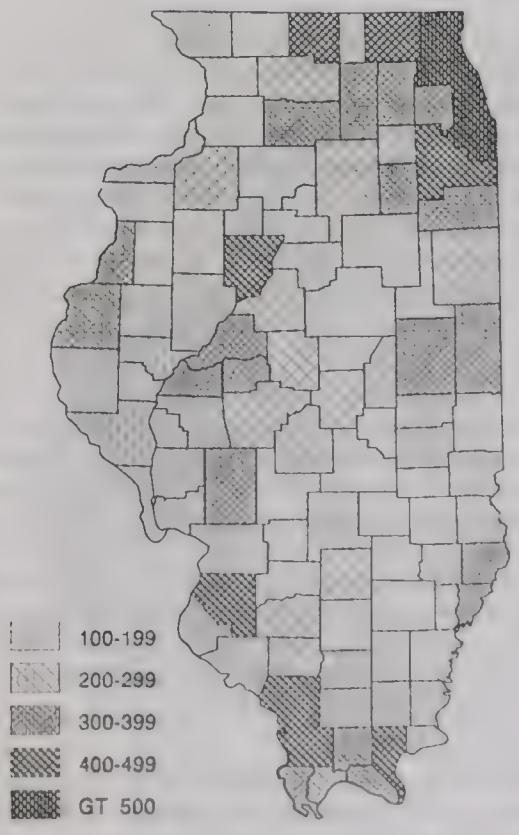

Figure 24. Number of native wetland plant species recorded from each Illinois county. Not all of these species can still be found in each county.

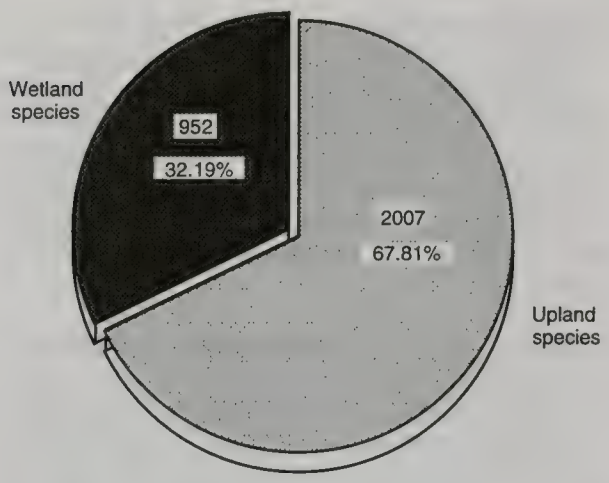

Figure 25. Percentage of wetland species in the Illinois vascular flora (native and non-native species).

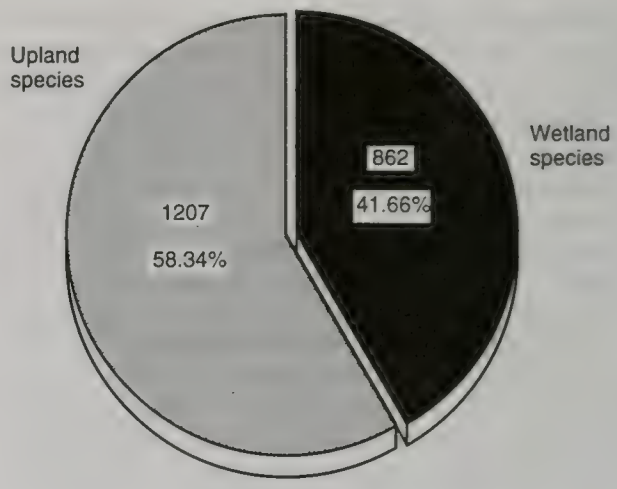

Figure 26. Percentage of wetland species in the native Illinois flora.

existing knowledge identifies the regions that support the greatest diversity of rare (Figure 31) as well as more common species (Figure 24).

An analysis of threatened and endangered wetland species by habitat type indicates, as previously mentioned, that the peatland bog and fen communities, each with 34, support the greatest number of threatened and endangered plant species (Figure 14). Another habitat that contains numerous rare wetland species, moist sand, is an amalgamation of several habitat types unified artificially by the similar characteristic of moist sand. These include portions of the Chicago lakeplain, margins of sand ponds, and moist sand prairie. Swamps (principally in southern Illinois), floodplain forests (also mostly those in southern Illinois), seeps and springs, pannes, and marshes also support more than 10 threatened and endangered wetland plant species each (Figure 14). Species extirpated from Illinois were not included in this analysis.

Approximately 34 wetland plant species appear to have become extirpated from the state, and these have been removed from the list of endangered species in Illinois (Bowles et al. 1991, Post 1991, Sheviak 1974, Taft 1993) (Table 7). Several additional wetland species still listed as endangered (Herkert 1991) are not presently known from extant Illinois populations, and at least one, the Illinois endemic thismia, may actually be extinct. Most, but not all, of these extirpated species were confined to wetlands in the north, specifically, the heavily urbanized northeastern counties.

Non-native Species

Distinguishing plant species that are native to Illinois from those that are non-native is important in understanding the value of high-quality wetlands. Non-native species, otherwise known as exotic, alien, or introduced species, are those that were not present in Illinois before European settlement of North America. Some non-native species have been introduced for landscaping or agricultural use, whereas others arrived as accidental hitchhikers from other regions. The percentage of non-native plant species in the overall flora of Illinois has risen from an estimated 10.2% in 1846 to 30.1% in 1988 (Figure 34) (Henry and Scott 1980, Reed 1988). By contrast, only 90 (9.4%) of the 952 wetland flora species are non-native, reflecting the greater association of non-native species with drier, more frequently disturbed habitats, such as agricultural fields and urban areas (Figure 35). This uneven distribution of non-native species over the wetness gradient can be further illustrated by ranking all plant species by wetness ranks (see previous section on wetland plant groups for explanation). The percentage of non-native species at each rank ranges from approximately 7.0% for those plants ranked –5 (OBL) to 48.0% for those species ranked 5 (UPL) (Figure 36) (Reed 1988). The percentage of wetland plants in Illinois that are non-native is unevenly distributed among the various habit groups (vines, ferns, trees, shrubs, sedges, grasses, and forbs). These values range from 4.8% of the shrub flora to 17.4% of the grasses. No non-native woody vines or ferns are found in the wetlands of Illinois (Figure 37) (Reed 1988).

Although the percentage of non-native species within the total wetland flora is low (9.4%), a few non-native plant species can have devastating effects in natural wetland habitats. Non-native species, once freed of the natural controls in their countries of origin, often spread rapidly and relatively unimpeded in their new habitats. The most deleterious effect of the invasion and establishment of non-native species in native plant and animal communities is a change in the plant community structure. An associated decrease in the plant and animal diversity of an area usually occurs, resulting in an overall loss in our natural heritage (Bratton 1982, Harty 1986). Other undesirable effects from non-native species can include changes in the nutrient balance in the soil, a lowering of the water table, and modifications to the disturbance regime (Bratton 1982). All Illinois counties have felt the deleterious impact of non-native species; however, nowhere in the state is the impact more important than in the counties of the greater Chicago area (Figure 38) (Reed 1988, Iverson 1992). In Illinois, over a four-year period (1989 through 1992) the Division of Natural Heritage in the Illinois Department of Conservation spent an average of 233 man-days/year (approximately $35,000/year in labor costs) on the control of non-native species in high-quality natural areas.

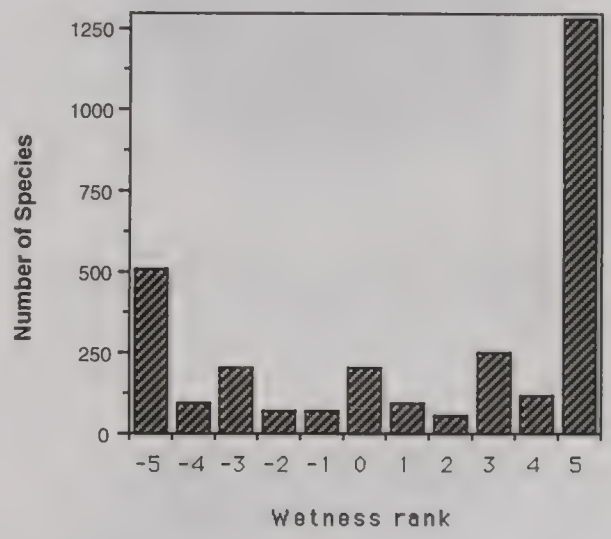

Figure 28. Number of Illinois plant species, including native and non-native species, occurring at each wetness rank. A rank of -5 indicates an obligate wetland species and a rank of 5 denotes an upland species. See text for additional information.

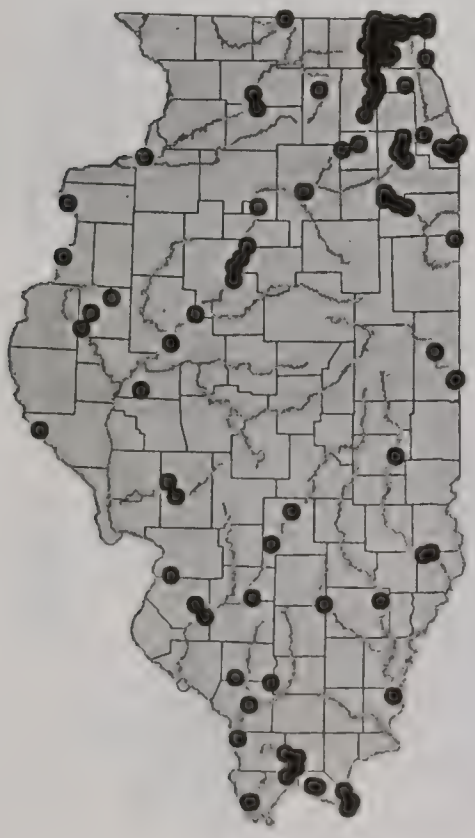

Figure 27. Locations of high-quality wetland communities identified by the Illinois Natural Areas Inventory. These are sites recognized as relatively undisturbed significant features (grades A and B).

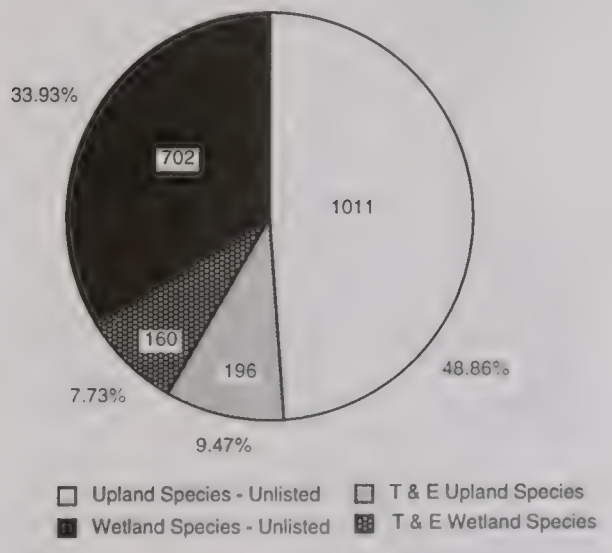

Figure 29. Number and percentage of species in the upland and wetland native Illinois flora listed as threatened and endangered.

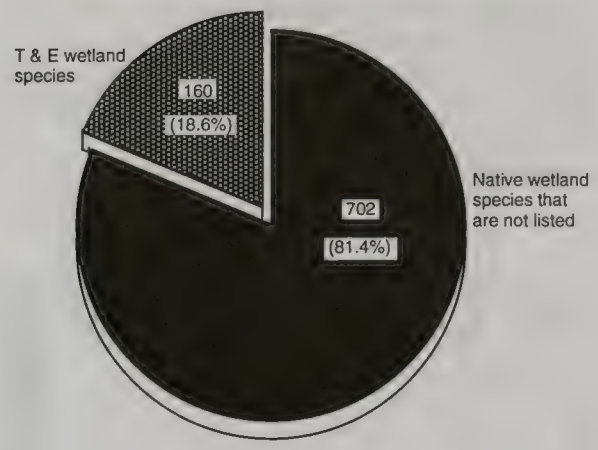

Figure 30. Number and percentage of native Illinois wetland flora listed as threatened and endangered species.

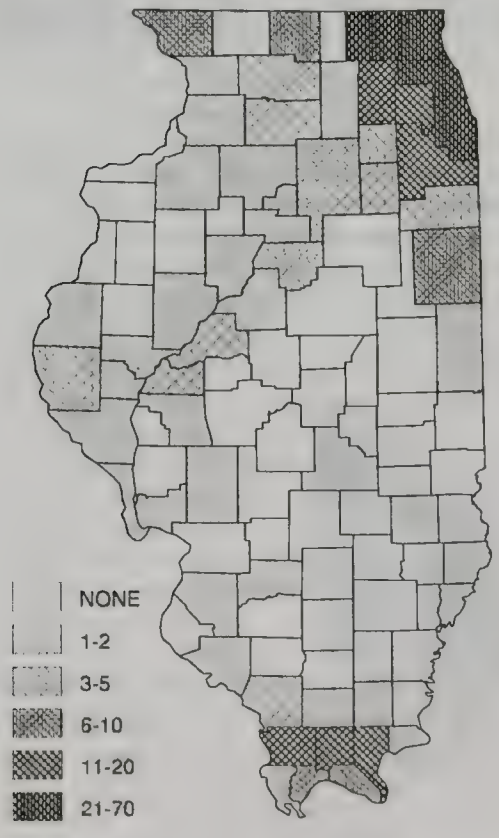

Figure 31. Number of threatened and endangered wetland plant species known from extant poulations in each Illinois county.

Despite a steady increase in the amount of time and money spent on control, the spread of these non-natives has continued (Francis M. Harty, Illinois Department of Conservation, personal communication).

The two most important non-native speciesthat seriously affect wetland habitats are purple loosestrife and glossy buckthorn. Purple loosestrife is a wetland plant from northern Europe, where it occurs in scattered locations in marshes and sea shores. Seeds of purple loosestrife probably arrived in North America in the early 1800s in ship ballast (Thompson et al. 1987). In the absence of natural predators and competitors in the New World, the plant spread rapidly in the northeastern United States during the 19th century, mainly along commercial shipping routes. By 1980, purple loosestrife had become firmly established in wetlands in the eastern United States and had spread to the West Coast (Schwegman 1985, Thompson et al. 1987). Once established in wetland habitats such as bogs, marshes, fens, and sedge meadows, and along reservoirs and ditches, the plants spread rapidly and displaced native

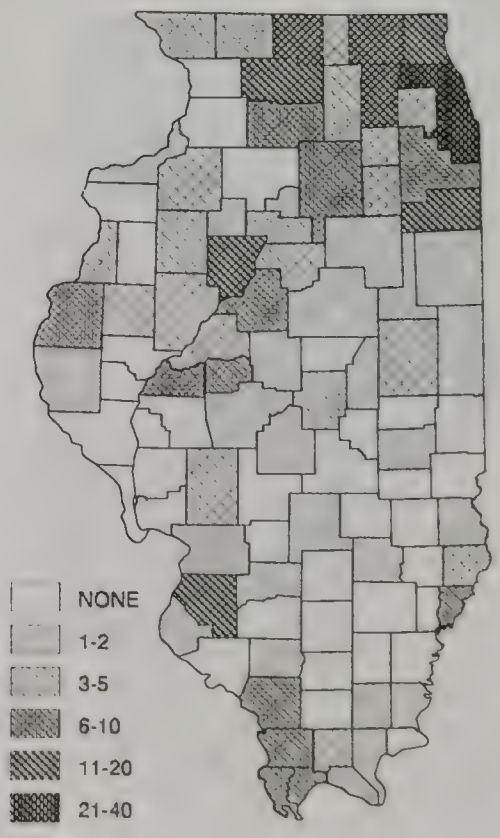

Figure 32. Number of extirpations of threatened and endangered wetland plant species in each Illinois county.

plants, thereby decreasing native plant diversity and habitat quality for wildlife (Heidorn and Anderson 1991).

Purple loosestrife reached Illinois sometime before 1940 (Thompson et al. 1987). In 1955, purple loosestrife was known from five counties (Jones and Fuller 1955); by 1985, it had spread to at least 25 counties (Figure 39) (Jones and Fuller 1955, Winterringer and Evers 1960, Mohlenbrock and Ladd 1978, Ladd and Mohlenbrock 1983, Mohlenbrock 1985). The most serious infestations are localized in the northeastern part of the state, an area with both high-quality wetlands and strong pressures from urban development. Purple loosestrife is now found in nearly all significant wetlands in the region, including those with high natural quality (Randy Heidorn, Illinois Department of Conservation, personal communication). Other parts of Illinois in which loosestrife has spread rapidly include wetlands along the Mississippi, Kankakee, Illinois, and Rock rivers (Schwegman 1985). Nationwide, the annual cost of the infestation for wildlife and agriculture is about $45 million (Thompson 1991). Purple loosestrife is designated as an exotic species by the Illinois Exotic Weed Act of 1988, which forbids its sale in Illinois (Gould and Gould 1991). Control of this pernicious non-native weed is difficult because of its ability to produce copious amounts of seed and to reproduce vegetatively by stem and root fragments. One solution for limiting the abundance of purple loosestrife may be the successful discovery and introduction of a biological control agent (Thompson et al. 1987).

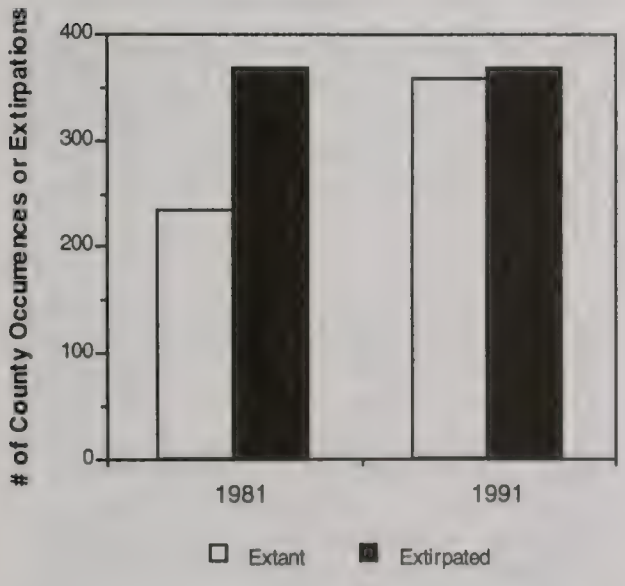

Figure 33. Number of county occurrences and county extirpations of threatened and endangered wetland species in Illinois, 1981 and 1991.

Glossy buckthorn, a European shrub, was brought to the United States for use as an ornamental plant and has now become established throughout the eastern states (Howell and Blackwell 1977). Glossy buckthorn was first documented in Illinois in 1912 at Skokie Marsh in northern Cook County (Sherff 1912). By 1978, the species had spread to 18 counties, mostly in northeastern Illinois (Figure 40) (Sherff 1912, Jones and Fuller 1955, Winterringer and Evers 1960, Mohlenbrock and Ladd 1978). Glossy buckthorn

Table 7. Wetland plant species thought to be extirpated from Illinois. This list does not include species still listed as endangered with no known extant populations in Illinois.

Common name	Scientific name
Bog rosemary	*Andromeda polifolia* var. *glaucophylla*
Dragon's mouth orchid	*Arethusa bulbosa*
Drooping wood reed	*Cinna latifolia*
Bluebead	*Clintonia borealis*
Early coral root	*Corallorhiza trifida*
Waterwort	*Elatine brachysperma*
Spike rush	*Eleocharis caribaea*
Horsetail spike rush	*Eleocharis equisetoides*
Marsh horsetail	*Equisetum palustre*
Brown plume grass	*Erianthus brevibarbis*
Umbrella grass	*Fuirena scirpoidea*
Purple avens	*Geum rivale*
Rattlesnake manna grass	*Glyceria canadensis*
Goldenpert	*Gratiola aurea*
Mare's tail	*Hippuris vulgaris*
Engelmann's quillwort	*Isoetes engelmannii*
St. John's wort	*Hypericum ellipticum*
Twinflower	*Linnaea borealis*
Water hyssop	*Mecardonia acuminata*
Mountain holly	*Nemopanthus mucronatus*
Phlox	*Phlox carolina* var. *angusta*
White-fringed orchid	*Platanthera blephariglottis*
Tall white orchid	*Platanthera dilatata*
Hooker's orchid	*Platanthera hookeri*
Marsh bluegrass	*Poa paludigena*
Pondweed	*Potamogeton epihydrus*
Pondweed	*Potamogeton vaseyi*
Spearwort	*Ranunculus ambigens*
Small yellow crowfoot	*Ranunculus gmelinii*
Bulrush	*Scirpus microcarpus*
Bulrush	*Scirpus pedicellatus*
Bulrush	*Scirpus subterminalis*
Least burreed	*Sparganium minimum*
Virginia chain fern	*Woodwardia virginica*

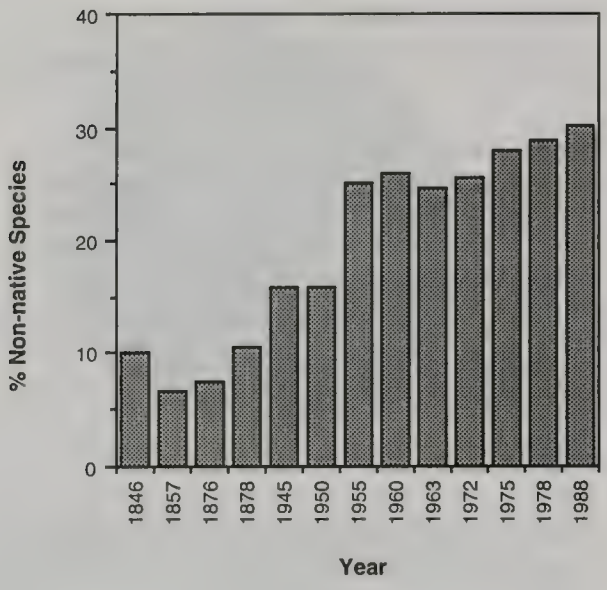

Figure 34. Percentage of non-native plant species in the Illinois flora, 1846 to 1988.

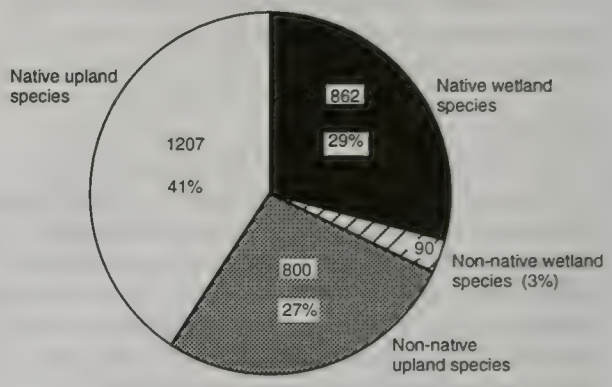

Figure 35. Number and percentage of native and non-native wetland and upland plant species in the Illinois flora.

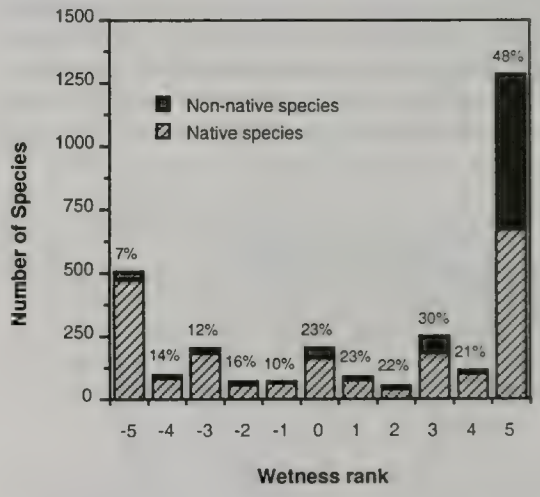

Figure 36. Abundance of non-native and native Illinois plant species at each wetness rank. (Values at top of bars represent the percentage of non-native species at each wetness rank. A wetness rank of –5 indicates an obligate wetland species; a rank of 5 indicates an upland species.

commonly invades bogs, fens, and sedge meadows (Heidorn 1991). The starling, a species of bird introduced from Europe and now a pest in North America, is the primary dispersal agent of glossy buckthorn fruits (Howell and Blackwell 1977). Once glossy buckthorn invades a natural wetland, it forms dense shrub thickets that overtop native shrubs and herbs, thereby decreasing the native biological diversity of the wetland (Taft and Solecki 1990, Heidorn 1991). Control methods for glossy buckthorn are labor intensive (Heidorn 1991), and the total infested acreage that can be treated using these methods is limited.

WETLAND ANIMALS IN ILLINOIS

Distribution, Diversity, and Abundance

The plant and animal communities found in wetlands are extremely complex and are intertwined through food webs and nutrient cycles. Wetlands abound with animal life. High proportions of bird, mammal, amphibian, and reptile species depend upon or utilize wetland habitats in Illinois (Figure 41). There is some degree of subjectivity in identifying animals as wetland species. Some wetland animal species are exclusively limited to wetlands, others may occur in upland or wetland habitats, and some may predominantly inhabit uplands.

Birds. Birds are unique among wetland inhabitants because many are migratory and rely on widely dispersed wetlands on a seasonal basis. Wetland plants provide cover, nest sites, and food for birds, and they provide habitat for other animals, such as insects, that are used for food (Benyus 1989). Many migrant species use wetlands for foraging and resting during migration (Figure 42), and some migrants may return each year to the same wetlands to feed and raise their young. Waterfowl, wading birds, shorebirds, and numerous songbirds depend upon wetlands. Some birds have highly specific habitat requirements, and others have more general habitat needs; therefore, the availability of a diversity of wetland habitats and wetland complexes is essential to support their populations.

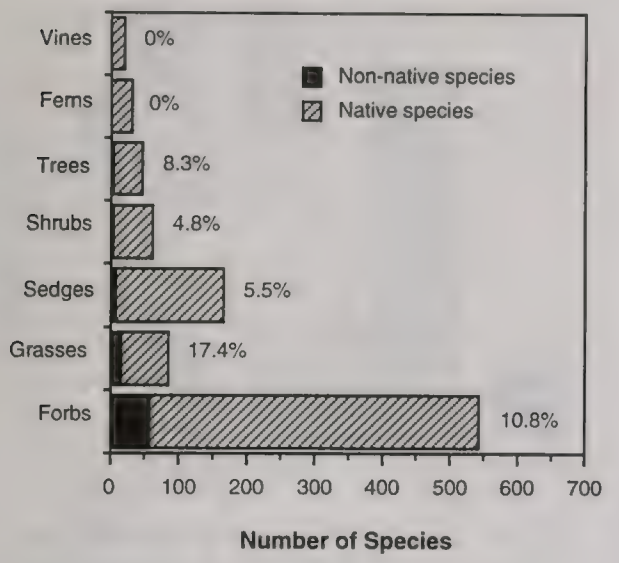

Figure 37. Number and percentage of non-native and native wetland plant species per growth habit group. (Values at end of bars represent the percentage of non-native species in each habit group.)

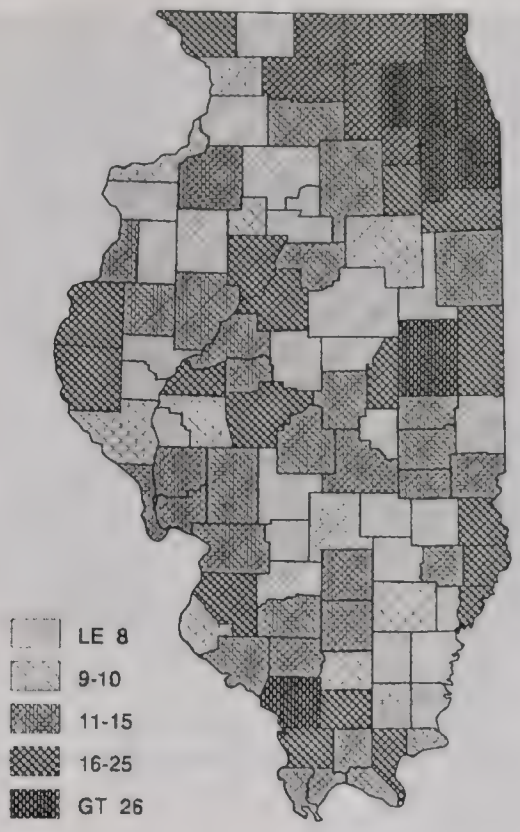

Figure 38. Number of non-native wetland plant species found in each Illinois county.

More than 439 bird species have been documented in Illinois. This discussion will address only the 274 more commonly observed species, including endangered or threatened species (Bohlen 1989) (see Appendix 3). The number of bird species using wetlands may be greater today than in presettlement times. As the land was cultivated and urbanized, those wetlands that were too wet or costly to develop remained as refugia in a disturbed environment. The mobility of birds allows them to exploit many types of habitat to fulfill their physiological requirements. Therefore, any of the 274 bird species listed in Appendix 3 can use wetlands for nesting, foraging, or resting during breeding, migration, or wintering seasons (Figure 41). Of these 274 species, 24 typically depend on wetland habitats for nesting or foraging sites, 81 are strongly associated with wetland habitats during their life cycles, and the remaining 169 use wetlands opportunistically at some time during the year.

Other than a study in northeastern Illinois by the Illinois Department of Conservation and aerial inventories by the Illinois Natural History Survey, no long-term studies of avian use of wetland habitats have been conducted in Illinois. Studies of this type are difficult because of the dynamic nature of wetland habitats. Wetland characteristics, such as water level and amount of vegetation cover, can change dramatically due to climatic effects or physical disturbance. Depending on the age of a wetland, water depth, annual temperature, and amount of precipitation, wetlands can vary from saturated to dry, or from open water to choked with vegetation, both seasonally and annually. Therefore, many wetland bird species are not guaranteed a predictable or favorable environment each year and must search out new and suitable wetlands in which to build their nests, or develop strategies to cope with these changing conditions. For example, one strategy, which allows birds that require standing water to nest in small, seasonal wetlands, is to breed relatively early in the season when standing water from winter thaw and spring rains is present. As these wetlands dry out, birds may move to more suitable habitats to raise their young (perhaps larger wetlands or lakes with more stable water levels).

The numbers and distributions of many species of wetland-dependent birds have decreased in response to the destruction and degradation of wetlands throughout the state (Bohlen 1989, Herkert 1992). Many of the wetland-dependent bird species are now listed as

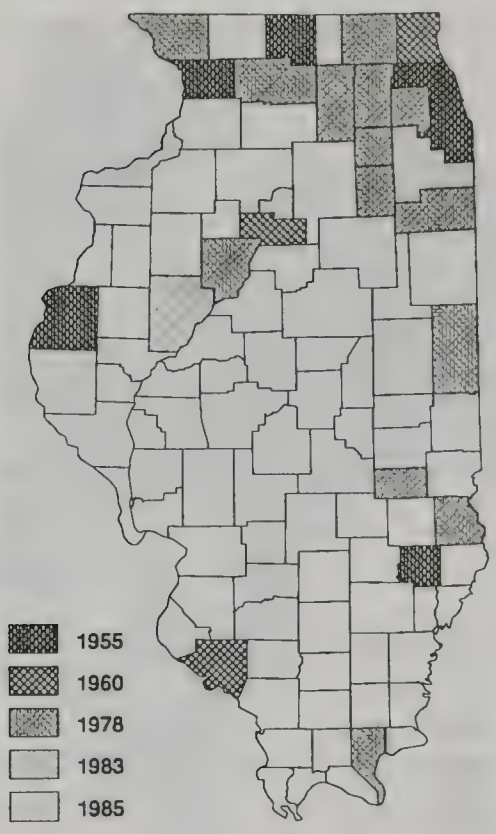

Figure 39. Spread of the non-native species purple loosestrife in Illinois counties by year first observed.

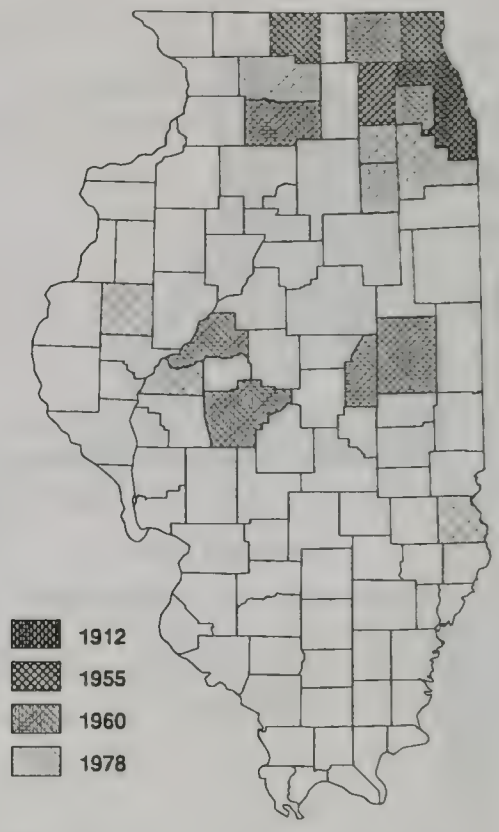

Figure 40. Spread of the non-native species glossy buckthorn in Illinois counties by year first observed

state-endangered or -threatened. The king rail is an example of a wetland-dependent species whose numbers have decreased because of wetland destruction. Ridgway (1895) noted that the king rail was a common summer resident in suitable habitat throughout the state. Today, the king rail is an occasional migrant and summer resident in Illinois. Bohlen (1989) noted that in view of its rarity today, the many historical nest records for the king rail in Illinois testify to its definite population decline.

Demographic data are scarce for many bird species that use wetlands as opportunists. It may be impossible to correlate population fluctuations or changes in occurrence for these species to changes in wetland habitats because these birds do not exclusively depend on wetlands and can shift their use among other habitats to fulfill their nesting, foraging, and resting needs. Also, true population trends of Illinois' bird species may be confounded by the increase in bird-watchers beginning in the 1970s. This increase in effort produced a greater number of observations at more locations for many bird species, but these data do not confirm an increase in population numbers or distribution. More research is needed to document bird species that opportunistically use wetland habitats in Illinois.

Colonial nesting bird species. Colonial bird species are those that nest in groups (Figure 43). Colonies can be composed of one species or several different species of birds. Colonial birds include the great blue heron, great egret, snowy egret, little blue heron, cattle egret, black-crowned night-heron, and the double-crested cormorant. Descriptions of heron colonies in Illinois date to 1888 (Barnes 1909), but many of the early published records are vague or incomplete, and the number of colonies and individuals can not be determined with any certainty (Graber et al. 1978).

Heron colonies are dynamic. Fluctuations in species composition and in the number of individuals are common. Lack of information on individual movements, annual variation, and problems with censusing heron colonies makes the evaluation of long-term population trends for these species difficult (Graber et al. 1978).

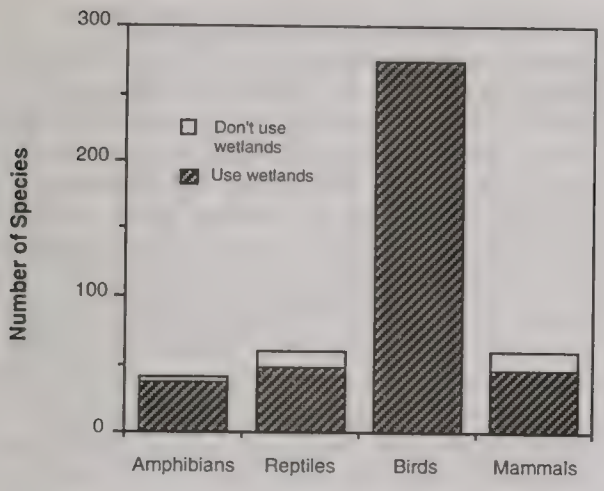

Figure 41. The proportion of amphibians, reptiles, birds, and mammals in Illinois that use wetlands.

Figure 42. Yellow-headed blackbird, one of many migrant bird species for which wetlands are important foraging and resting sites. (Photo taken at McKee Marsh, Dupage County, Illinois, by Joe Milosevich).

Graber et al. (1978) investigated historical information and conducted censuses of colonies from 1973 to 1977. Broad-scale estimates of colony numbers from before 1900 through 1977 are available (Figure 44). The Illinois Department of Conservation began intensive heron colony surveys (both aerial and ground) in 1983. Most of the Department's censuses were aerial estimates (less accurate than ground counts), and all colonies were not censused in each year; however, the aerial censuses illustrate general overall trends in numbers of colonies, species, and individuals for colonial nesting birds in the state.

Data suggest that larger, long-lived colonies, most of which contain more than one species, typically occur in floodplain forests along major rivers and reservoirs. Smaller colonies, typically composed of only great blue herons, occur in floodplain forests and smaller woodlots that are either near or away from water. Herons and egrets also nest in scrub-shrub and emergent wetlands. Herons, egrets, and double-crested cormorants depend on shallow-water and deep-water wetlands as foraging habitat; the more terrestrial cattle egret is an exception.

Total numbers of great blue herons, great egrets, and double-crested cormorants have increased since 1983, but black-crowned night-herons have decreased in number (Figure 45). Insufficient data are available to document population trends for snowy egrets and little blue herons, which were never very common in the state, or cattle egrets, a self-introduced exotic (Graber et al. 1978). There were approximately 30 known heron nesting colonies in Illinois in 1983, and the number increased to 38 in 1991 (Figure 46). Both great blue herons and great egrets have increased their numbers of breeding colonies in the state, but the black-crowned night-heron has decreased its number of nesting locations (Figure 47). An increase in observers in recent years has added to the number of heron colony locations and nests counted; however, these increases are not confirmation of true population increases. Special attention must be given to those species that, in spite of increased census efforts, appear to be decreasing in distribution or population numbers (e.g., the black-crowned night-heron) (Figure 48).

Since the turn of the century, herons and egrets have suffered population declines because of plume hunters, hydrocarbon pollution, vandalism, human encroachment, and habitat destruction (Graber et al. 1978). Protective legislation prohibits the persecution of these species, but habitat manipulation and destruction continues to be a major threat.

Waterfowl. *Dabbling ducks.* In Illinois, the mallard is the most abundant species of duck (Figure 49). The Illinois River valley historically has been one of the most important migration areas for mallards in the United States. Frederick Lincoln, the first person to

band ducks in the United States, placed bands on mallards in 1922 in the Illinois River valley. Lincoln noted that "when all the other ducks are gone, there will still be mallards on the Illinois" (Heilner 1943:88).

Peak population numbers are an excellent indicator of the changes in the numbers of various species of waterfowl occurring in an area from year to year. The peak population number is the highest number of individuals of a species that was inventoried in a region on any one of the several aerial censuses conducted by the Illinois Natural History Survey during each fall. Inventory data for peak numbers of waterfowl are presented in Figures 50–52 as a three-year moving average, with the data plotted on the third year, to minimize annual fluctuations and emphasize long-term trends.

Plotting the peak counts of mallards during fall in the Illinois River and the central Mississippi River regions from 1948 to 1991 (Figure 50) indicated that the Illinois River region from Henry to Grafton has generally accommodated higher numbers of mallards than the central Mississippi River region from Grafton to Rock Island. For example, a peak number of 1,617,575 mallards was recorded for the Illinois River region as compared with 181,405 in the central Mississippi River region in 1948. In recent years, however, the difference in the peak numbers of mallards in these two regions has become smaller. A significant ($P < 0.005$) downward trend in mallard numbers was documented in the Illinois River and central Mississippi River regions separately and also combined during 1948–1991 (Havera 1992). The number of mallards in North America has been declining in recent decades, and the downward trend in the numbers of mallards observed in the Illinois and central Mississippi River regions is influenced by the overall number of mallards in North America. However, wetlands in the Illinois River valley have been degraded by sedimentation, which has greatly reduced the variety and abundance of aquatic plants and other natural foods available to mallards. Thus far, the aquatic plant life of the Mississippi River has been less affected by sedimentation, but detrimental effects are becoming apparent. In addition, increased tillage of harvested corn fields in central Illinois during fall sharply decreased the waste grain resource for mallards and other field-feeding species (Warner et al. 1985).

The Illinois River and central Mississippi River regions are extremely important to mallards. From 1953 to 1991, an average of 22.7% of all the mallards wintering in the Mississippi Flyway were in the Illinois River region during one day of the fall migration. Similarly, an average of 14.7% of all the mallards wintering in the Mississippi Flyway were in the central Mississippi River region during one day of the fall migration. For both regions, an average of 35.4% of all the mallards wintering in the Mississippi Flyway passed through the Illinois and central Mississippi River regions (Havera 1992).

Diving ducks. The drastic decline of the lesser scaups and canvasbacks in the Illinois River region and the

Figure 43. Colonial bird species (great blue heron, great egret, double-crested cormorant are pictured) nesting at the Lake Renwick Heron Colony in Will County. (Photo taken by Joe Milosevich.)

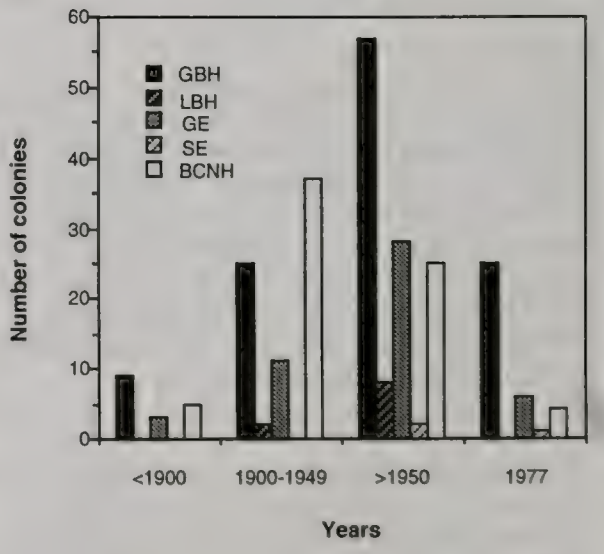

Figure 44. Estimated number of heron colonies in Illinois, before 1900 to 1977 (GBH = great blue heron, GE = great egret, LBH = little blue heron, BCNH = black crowned night-heron, SE = snowy egret).

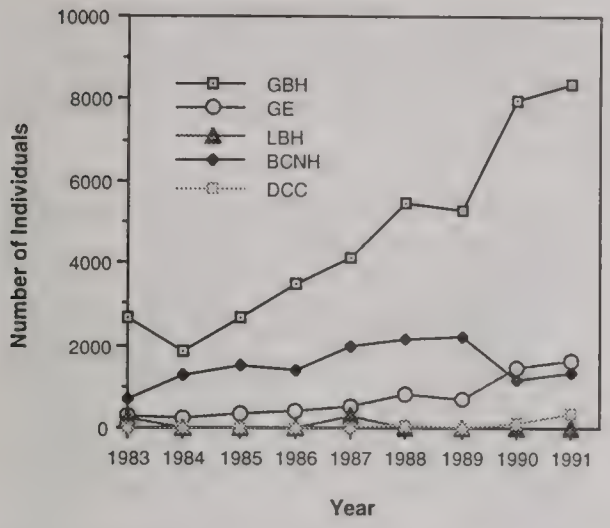

Figure 45. Number of individuals of five colonial bird species that use Illinois wetlands, 1983 to 1991 (GBH = great blue heron, GE = great egret, LBH = little blue heron, BCNH = black crowned night-heron, DCC = double-crested cormorant).

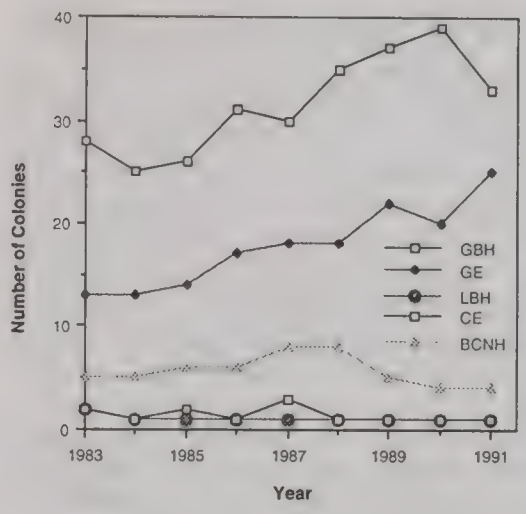

Figure 46. Number of colonies of five heron species in Illinois, 1983 to 1991 (GBH = great blue heron, GE = great egret, LBH = little blue heron, CE = cattle egret, BCNH = black crowned night-heron).

subsequent increase in numbers of these species in the central Mississippi River region are particularly noteworthy. The plant and animal food resources utilized by lesser scaups, canvasbacks, and other species of diving ducks began disappearing from the upper Illinois River valley in the mid-1950s and have not recovered. The aquatic plants in the Illinois Valley were affected by sedimentation (Bellrose et al. 1979, Havera and Bellrose 1985), and the benthic macroinvertebrate community was likely affected by toxins, possibly high concentrations of ammonia (R.E. Sparks, Illinois Natural History Survey, personal communication).

Pool 19 (Keokuk Pool) of the Mississippi River is the most important migration area for diving ducks in the Midwest. Pool 19 has hosted large and varying numbers of lesser scaups and canvasbacks and reasonable numbers of other species. Because of recent dramatic fluctuations in the aquatic plant and animal populations, the outlook for the food base of diving ducks in Pool 19 and elsewhere in the upper Mississippi River is dubious. Additionally, human disturbance has been documented to affect adversely the numbers of diving ducks on Pool 7 and Pool 19 (Korschgen et al. 1985, Havera et al. 1992).

Lesser scaups were abundant in the Illinois Valley before the mid-1950s. The decline in the numbers of lesser scaups utilizing the Illinois River region and the

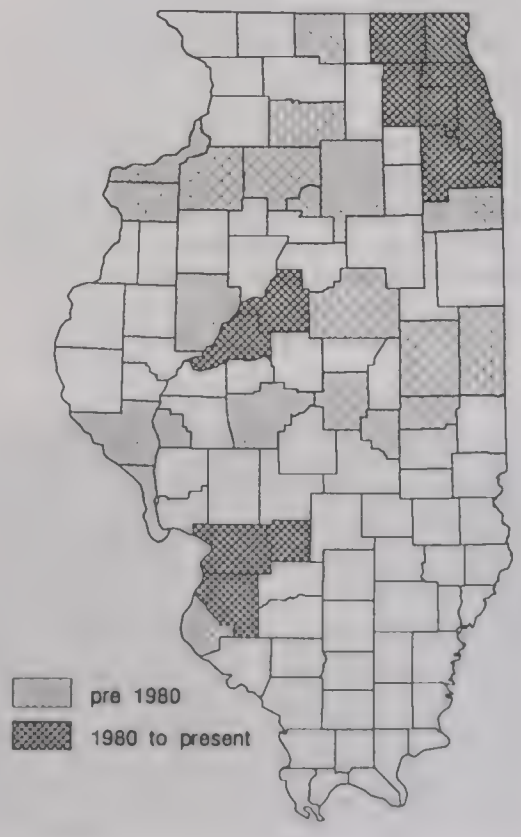

Figure 47. Counties in which nesting black-crowned night herons were found before and after 1980.

increase in the numbers stopping on Pool 19 in the central Mississippi River region since 1948 are apparent (Figure 51) (Havera 1992). The crash in the peak numbers of lesser scaups, primarily on renowned Upper Peoria Lake, occurred in the 1950s. The peak numbers of lesser scaups recorded in the Illinois River region from Peoria northward were 585,100 in 1954, 73,650 in 1955, 34,250 in 1956, and 10,075 in 1957. Subsequently, the numbers of lesser scaups stopping in this stretch of the Illinois River have never recovered. On Pool 19 in the central Mississippi River region, however, numbers of lesser scaups began to increase steadily after 1950 and reached a zenith of 686,500 in 1969. Unfortunately, the trend in lesser scaup numbers has been downward since then. In 1991, only 19,050 lesser scaups were observed on the Mississippi River from Keokuk, Iowa, to Rock Island, Illinois—the lowest number since the aerial inventories were begun in 1948 (Havera 1992).

The highest number of canvasbacks inventoried in the Illinois River region occurred on the beds of aquatic vegetation on Upper Peoria Lake, where 95,000 were present in November 1953 and 85,000 were recorded in October 1952 (Havera 1992). The peak number of canvasbacks recorded in the Illinois River region north of Peoria was 105,160 in 1952 and 103,500 in 1953; in 1971, a maximum of 120 were observed there (Figure 52). Similar to the numbers of lesser scaups, the numbers of canvasbacks crashed in the Illinois River region in the mid-1950s. The numbers of canvasbacks had not recovered to any reasonable levels by 1991. In the central Mississippi River region, the numbers of canvasbacks began to increase in 1963, mainly on Pool 19, and, after a downturn in the mid-1970s, reached their maximum number of 188,150 in 1978. Since 1978, the number of canvasbacks has been sliding downward in this stretch of the Mississippi River; only a maximum of 22,765 were observed there in 1989 (Havera 1992).

Mammals. Of the 59 species of mammals in Illinois, at least 46 use wetland habitats (Hoffmeister 1989,Hofmann 1991) (Figure 41, Appendix 4). Relatively few mammal species are specifically adapted for living in wetlands (Fritzell 1988), but wetlands provide abundant food (e.g., invertebrates, amphibians, waterfowl eggs and nestlings) and cover for a variety of mammals. Larger mammals, such as the bobcat and white-tailed deer, have home ranges that can encompass a mosaic of

Figure 49. The mallard, the most abundant duck in Illinois during fall migration.

Figure 48. The black-crowned night heron, whose numbers have been declining in Illinois. (Photo taken at Channahon, Will County, by Joe Milosevich.)

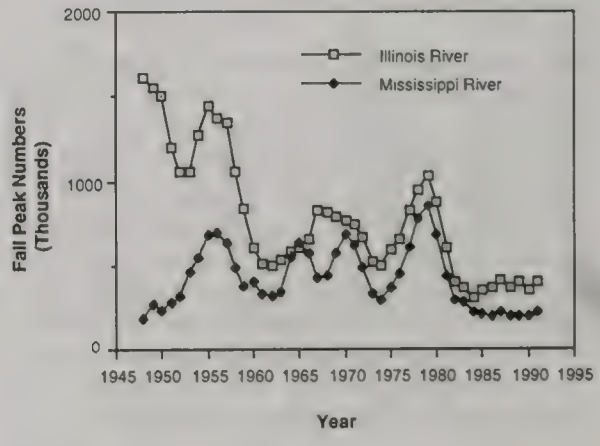

Figure 50. Peak numbers (3-year moving average) of mallards aerially inventoried during fall in the Illinois and central Mississippi River regions, 1948 to 1991.

forested and open habitats, including wetlands. Some species of small mammals (insectivores and rodents) have broad environmental tolerances, and individuals can be found in a range of habitats from wetlands to uplands.

The Virginia opossum occupies a variety of habitats but is often found near water. Most shrews require moist microclimatic conditions; four Illinois species are known to occur in wetlands but are not restricted to them (Hoffmeister 1989, Mumford and Whitaker 1982). The eastern mole occurs in both forests and open habitats, including areas that are periodically inundated (Mumford and Whitaker 1982). Bats are not typically considered wetland animals, but all 12 species that occur in Illinois are listed in Appendix 4 as mammals that use wetlands. Bats forage in and above floodplain forests and above ponds, marshes, and bogs as well as in and above upland forests, above streams and fields, and near buildings (Barbour and Davis 1969, Hoffmeister 1989). In addition, most bat species in Illinois roost in trees, at least occasionally, during the summer and could use floodplain forests for that purpose. The importance of floodplain forests as bat habitat is indicated by recent captures of all species that occur in Illinois along the Cache River (Illinois Natural History Survey and Illinois Department of Conservation, unpublished data). The swamp rabbit inhabits only bottomland forest and swamps in southern Illinois (Hoffmeister 1989, Kjolhaug et al. 1987). Sixteen species of rodents can be found in wetlands, although few are limited to such habitats (Hoffmeister 1989, Mumford and Whitaker 1982). The rodents most closely associated with wetlands are the beaver, muskrat, and marsh rice rat. Ten of Illinois' carnivore species use wetland habitats; ponds and emergent wetlands, for example, are good hunting areas for predators. The carnivores most strongly associated with wetlands are the raccoon, mink, and river otter. The white-tailed deer (the largest mammal still present in Illinois) uses wetlands, especially forested wetlands, for foraging and cover. Several of the mammal species that utilize wetlands are of economic importance as furbearers or game animals.

Continued losses of wetlands to agriculture and urbanization would decrease the amount of suitable habitat available to the majority of mammal species in Illinois. This loss would have the greatest impact on the species that are limited to or primarily found in wetland habitats. Two such wetland species are the marsh rice rat and swamp rabbit, which both have limited ranges in the state and occur in scattered populations that are vulnerable to local extirpation (Hofmann et al. 1990, Kjolhaug et al. 1987). Destruction and fragmentation of bottomland forest has already had an adverse impact on the swamp rabbit (Kjolhaug et al. 1987). In Illinois, historical records suggest that this species was once widely distributed in the Mississippi, Big Muddy, Kaskaskia, Ohio, Cache, Wabash, Little Wabash, and Saline river drainages, occurring as far north as Calhoun, Bond, and Lawrence counties (Kjolhaug et al. 1987) (Figure 53). During extensive searches in 1984 and 1985, swamp rabbits were found at 22 locations in only eight counties (Kjolhaug et al. 1987) (Figure 53). Similar declines in swamp rabbit numbers as a result of habitat loss have been noted in

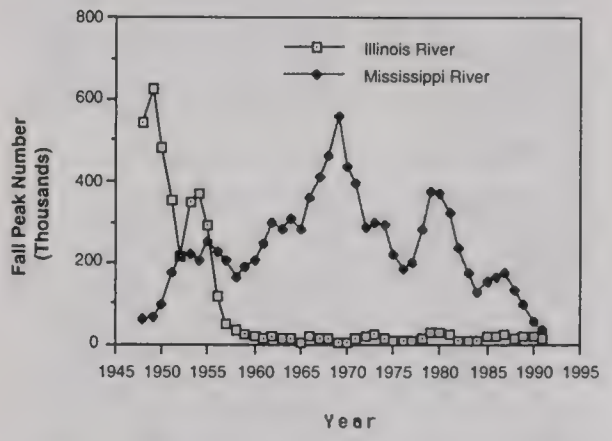

Figure 51. Peak numbers (3-year moving average) of lesser scaups aerially inventoried during fall in the Illinois and central Mississippi River regions, 1948 to 1991.

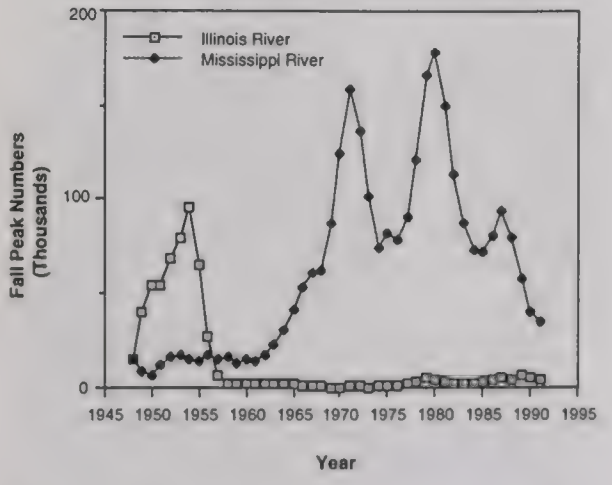

Figure 52. Peak numbers (3-year moving average) of canvasbacks aerially inventoried during fall in the Illinois and central Mississippi River regions, 1948 to 1991.

Missouri and Indiana (Korte and Fredrickson 1977, Whitaker and Arbell 1986).

Amphibians. Amphibians are an important component of many ecosystems. They can constitute a large proportion of the total vertebrate biomass of an ecological community (Burton and Likens 1975). They also are a vital link in food webs. Amphibians are major consumers of arthropods, mollusks, and annelids, and they can have a significant role in insect control. Amphibians, in turn, are an important source of food for many predatory fish, reptiles, birds, and mammals. Because the life history of most amphibians includes both aquatic and terrestrial stages, 37 of the 41 amphibian species that occur in Illinois use wetland habitats at least part of the time (Smith 1961; Conant and Collins 1991; R.A. Brandon, Southern Illinois University, personal communication; C.A. Phillips, Washington University, personal communication) (Figure 41, Appendix 5).

Most salamanders are aquatic as larvae and terrestrial as adults, although adults require moist microclimatic conditions because of their susceptibility to desiccation. Twenty species of salamanders occur in Illinois (Morris et al. 1983, Phillips 1991), and most of these (16) use wetland habitats at least for breeding and larval development. The ambystomatid salamanders (eight species) are terrestrial or fossorial as adults; most of these species inhabit swamps or floodplain forest, although some may also occur in moist, wooded upland areas (Smith 1961). All use permanent ponds or vernal pools for breeding. The adult eastern newt has both terrestrial and aquatic stages, with the aquatic form occurring in ponds and marshes (Smith 1961). Three Illinois plethodontids are completely terrestrial (no aquatic larval stage) and typically are found on wooded hillsides, but five other plethodontids in the state occur in springs, seeps, bogs, and swamps (Smith 1961; C.A. Phillips, Washington University, personal communication; R.A. Brandon, Southern Illinois University, personal communication). The mudpuppy, primarily an inhabitant of lakes, rivers, and large streams, probably occurs in wetlands as well (R.A. Brandon, Southern Illinois University, personal communication). The lesser siren is permanently aquatic, inhabiting swamps, ditches, and sloughs (Smith 1961). All 21 species of anurans (frogs, tree frogs, and toads) that occur in Illinois (Morris et al. 1983, Hedges 1986) have an aquatic larval stage and rely on ponds, marshes, or seasonally flooded areas during the breeding season (Smith 1961). As adults some frogs and toads remain in or near ponds, marshes, or swamps, whereas others wander quite far from water (Smith 1961).

Temporary and seasonal wetlands are important to amphibians. Because their eggs and larvae are highly vulnerable to predation by fish, many amphibians that breed in water rely on wetlands in which standing water is not present long enough to support fish populations (Environmental Defense Fund and World Wildlife Fund 1992). Nineteen species of amphibians in Illinois depend upon temporary wetlands, such as vernal woodland ponds, flooded fields, or roadside ditches, for breeding (Morris 1991). Therefore, if the removal of legal protection from temporary and seasonal wetlands resulted in an increased loss of these types of areas, amphibian populations (and, consequently, the reptiles, birds, and mammals that feed upon them) would be adversely affected (Environmental Defense Fund and World Wildlife Fund 1992).

Amphibians in many parts of the world recently have undergone decreases in numbers and geographical ranges. The declines of some populations have been dramatic, and a few species, such as the gastric brooding frog of Australia and the golden toad of Costa Rica, have virtually disappeared in a short period of

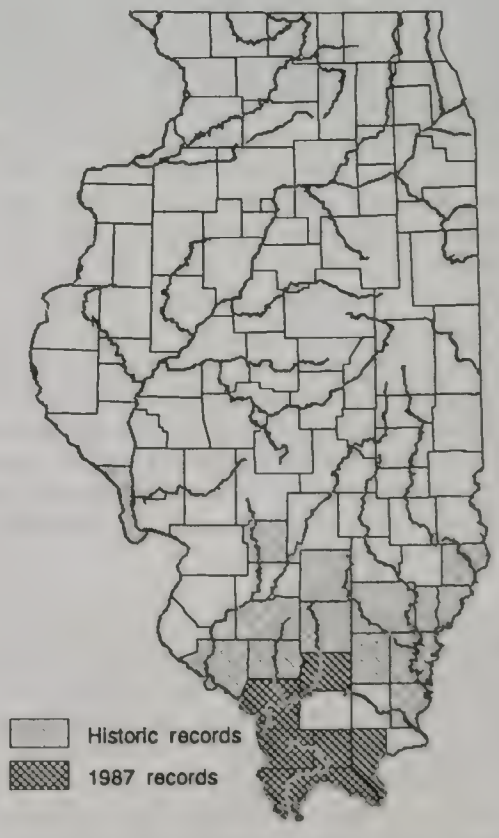

Figure 53. Historical and recent records of the swamp rabbit in Illinois. Source: Kjolhaug et al. 1987.

time (Blaustein and Wake 1990; Phillips 1990, 1991; Wake 1991; Livermore 1992). The situation is complex because not all species of amphibians have experienced declines. Also, amphibian populations fluctuate greatly from year to year, and stochastic events could explain the local extirpation of populations when numbers are at low levels (Pechmann et al. 1991, Wake 1991). Many scientists, nonetheless, have concluded that there is a global problem facing amphibians, and that it is largely the result of habitat modification by humans (Blaustein and Wake 1990).

No single factor can explain all the declines in amphibian populations. Some losses are directly attributable to habitat destruction, but in other cases amphibian populations have decreased in habitats that appear undisturbed (Blaustein and Wake 1990). More subtle forms of habitat modification are implicated in these declines. Because of their permeable skin and their exposure to both aquatic and terrestrial conditions, amphibians are especially susceptible to environmental stresses and can serve as bioindicators of these stresses (Blaustein and Wake 1990). Acid deposition is a problem for some species, including episodic acidification of wetlands or streams during the breeding season caused by snowmelt (Wyman 1990, Livermore 1992). Other factors that have been proposed as adversely affecting amphibian populations include changes in precipitation patterns (possibly a reflection of global warming), increased levels of ultraviolet radiation (a consequence of ozone depletion), pollution by pesticides or heavy metals, and the introduction of predators (Blaustein and Wake 1990, Phillips 1990, Wyman 1990).

Little quantitative information exists on long-term trends in amphibian populations in Illinois, but the Midwest does not seem to be experiencing the drastic declines occurring elsewhere (C.A. Phillips, Washington University, personal communication). Nonetheless, habitat loss has undoubtedly had an adverse effect on local populations within the state and has probably restricted the range of at least one species. Smith (1961) believed that the eastern newt originally occurred throughout Illinois but had disappeared from the central portion of the state because of deforestation and draining of prairie marshes.

Of the 37 amphibian species that use wetlands, seven salamanders and five anurans have very limited distributions because Illinois lies at the edge of their ranges (Smith 1961, Conant and Collins 1991). In addition, the four-toed salamander occurs only as relict populations in scattered locations, only one native population of the silvery salamander is known in the state, and populations of the Illinois chorus frog are disjunct. These species would be especially vulnerable to continued loss of wetland habitat or detrimental changes in the environmental conditions of wetlands.

Reptiles. Reptiles, as a group, are less dependent on water than are amphibians. Nevertheless, many reptiles are aquatic, including a large proportion of turtles and several snakes. Of the 60 species of reptiles that occur in Illinois (Morris et al. 1983), at least 47 species utilize or depend upon wetland habitats (Smith 1961; Conant and Collins 1991; R.A. Brandon,Southern Illinois University, personal communication; C.A. Phillips, Washington University, personal communication; S.R. Ballard, Illinois Department of Conservation, personal communication) (Figure 41, Appendix 6).

Most turtles in Illinois are aquatic or semi-aquatic, and 15 of the 17 turtle species in the state occur in wetlands (Smith 1961; R.A. Brandon, Southern Illinois University, personal communication). Ten of these species are not restricted to wetlands and are also found in other aquatic habitats. The snapping turtle and common musk turtle, for example, are common in ponds throughout Illinois, but they also inhabit streams, rivers, and lakes. Eight species occur in marshes, sloughs, or swamps as well as streams, rivers or lakes (Smith 1961). The eastern mud turtle, Illinois mud turtle, and Blanding's turtle, all rare in Illinois, occur only in wet meadows, marshes, sloughs, or ponds (Smith 1961). The very rare spotted turtle is found only in sedge meadows in Illinois (Herkert 1992). The terrestrial eastern box turtle inhabits floodplain and upland forests (Smith 1961).

Only six species of lizard are known to occur in Illinois (Morris et al. 1983). Four of these—the eastern fence lizard, five-lined skink, broadhead skink, and ground skink—can occur in floodplain forests (Conant and Collins 1991; R.A. Brandon, Southern Illinois University, personal communication; C.A. Phillips, Washington University, personal communication).

Twenty-eight of the 37 species of snakes in Illinois occur in wetlands (Smith 1961; Conant and Collins 1991; R.A. Brandon, Southern Illinois University, personal communication; C.A. Phillips, Washington University, personal communication; S.R. Ballard, Illinois Department of Conservation, personal communication). Seven species of water snakes inhabit ponds, marshes, sloughs, and swamps (Smith 1961). The eastern and western ribbon snakes are semi-aquatic and seldom venture far from ponds, marshes, or swamps

(Smith 1961, Conant and Collins 1991). Garter snakes occur in a variety of habitats, including bogs and the edges of marshes or ponds (Minton 1972, Conant and Collins 1991). The mud snake is an inhabitant of swamps and sloughs in southern Illinois (Smith 1961). Other species of colubrid snakes that can be found in wetlands include the worm, smooth green, racer, brown, smooth earth, and eastern hognose snakes (Smith 1961; R.A. Brandon, Southern Illinois University, personal communication). The great plains rat snake is typically an upland species but is included as a wetland species because it occurs in a marsh in Monroe County (R.A. Brandon, Southern Illinois University, personal communication). All four pit vipers use wetlands; the cottonmouth inhabits swamps and sloughs during the summer, the massasauga is an inhabitant of marshes and bogs, and the timber rattlesnake and copperhead sometimes occur in floodplain forest (Smith 1961). Snakes of other species may visit ponds or the edges of marshes or swamps to feed upon amphibians or drink.

There are no long-term quantitative data on the abundance of reptiles in Illinois. The draining of prairie marshes in central Illinois is thought to have had an adverse impact on the distribution and abundance of reptiles. Blanding's turtle was once probably abundant in the northern half of Illinois but in recent years has occurred as scattered colonies with a discontinuous distribution (Smith 1961). Similarly, the massasauga was probably common throughout the northern four-fifths of Illinois (Smith 1961). Both of these species have been placed on the Illinois Department of Conservation's watch list.

Fish. Wetlands also serve as breeding grounds for many species of fish. The status of fish populations in Illinois is addressed in the chapters on flowing waters and lakes and impoundments.

Invertebrates. Invertebrates are the least conspicuous but most abundant animals in any wetland habitat, and they play an essential role in making plant energy available to other animals. Among the invertebrates present in Midwestern wetlands are protozoa, sponges, flatworms, worms, crustacea, mollusks (clams and snails), and insects. Although most of the insects are terrestrial, a significant number (about 10%) are adapted for living in water. Among the fairly common insects of wetlands are crawling water beetles, giant water bugs, water scorpions, dragonflies, and mayflies. In some types of wetlands, such as deep- and shallow-water marshes, mollusks are dominant and form an important food source for fish and diving ducks. The presence of unionid mollusks is also a fairly reliable indicator of relatively clean, pollution-free water.

Trend information for macroinvertebrate communities of lentic wetlands in Illinois is lacking, although some faunal studies of species groups are available. Macroinvertebrates are acknowledged as important components of wetland ecosystems; they are, for example, an essential food source for waterfowl and fish and are important in processing organic matter. Macroinvertebrate communities are certainly as different as wetlands themselves. Factors influencing macroinvertebrate communities include the predictability and seasonality of drying as well as the volume and depth of open water.

Several faunal studies conducted in Illinois have addressed taxa that are important in wetlands, including mosquitoes (Ross 1947, Ross and Horsfall 1965) and horse flies and deer flies (Pechuman et al. 1983). In particular, mosquitoes are well known as nuisances and disease carriers. Mosquitoes in Illinois have been the subject of more than 400 scientific and popular papers in this century, and the control of pest species has cost millions of dollars (Baumgartner 1990). Over 60 species of mosquitoes are found in the state, but few are serious pests and not all bite humans. The habitat requirements of mosquito species vary greatly, and though most require wetlands for breeding habitat, some take advantage of artificial sites, such as water in tire piles, refuse heaps, and containers inside buildings.

Threatened and Endangered Species

Vertebrates. Forty-five percent (94) of the 209 federally listed threatened and endangered animal species are wetland-dependent or wetland-related (Feierabend and Zelazny 1987). Ninety-four species of vertebrates are listed as threatened or endangered in Illinois (Herkert 1992). The majority of these species (64%) either depend upon or utilize wetland habitats at least during one stage of their life cycle (e.g., larval development) or for specific functions (e.g., foraging) (Figure 54). The number of threatened and endangered vertebrate species dependent upon wetlands recorded in each county in Illinois since 1980 is shown in Figure 55 (Herkert 1992, Illinois Natural Heritage Database).

Birds. Of the 43 species listed as endangered and threatened in Illinois, 30 are strongly associated with wetland habitats (especially during the breeding

season), and the remaining 13 can use wetland habitats opportunistically throughout the year (Bohlen 1989, Herkert 1992, Illinois Fish and Wildlife Information System). The 30 species that are strongly associated with wetlands are listed in Table 8. These species may use one particular type of wetland habitat or several types to fulfill life history requirements; for example, the great egret (Figure 56) typically nests in floodplain forests but prefers to forage in shallow-water wetlands. Twenty-five species of endangered and threatened birds use shallow-water wetlands for nesting and foraging, 12 use floodplain forests for nesting, foraging, or resting, nine use deep-water wetlands and lakes to forage, and eight use other types of wetlands, such as sedge meadows, wet prairie, mudflats, sandbars, etc. (Bohlen 1989, Herkert 1992, Illinois Fish and Wildlife Information System)

Habitat destruction or degradation is likely to be responsible for the decline of 23, and range reductions of 15, endangered and threatened bird species in Illinois (Herkert 1992). For example, since 1980, the black tern's breeding range has decreased to four northeastern Illinois counties (Figure 57). From 1980 through 1989, black terns were observed at 19 wetlands in these four counties but nested at only nine of the sites (Heidorn et al. 1991) (Figure 58). Before 1985 this species had 77 nests in five wetlands, but after 1985 there were 50 nests in eight wetlands (Heidorn et al. 1991). Although the local distribution of black terns may appear to be increasing slightly, its population numbers are decreasing. As larger wetlands are fragmented or destroyed, black terns, like other wetland-dependent birds, must search for new and perhaps less suitable nesting sites that may not support large population numbers. Therefore, despite their mobility, wetland destruction and degradation may cause populations of endangered and threatened bird species to become small and scattered, thereby jeopardizing their continued existence in the state.

Bald Eagles. Bald eagles have been present in what is now Illinois for thousands of years. The first documented presence of eagles dates back 400 to 800 years based upon the remains of at least 16 bald eagles identified by Parmalee (1958) from Indian burial sites in Cahokia. The Illinois and Mississippi river floodplains were once commonly used for nesting by bald eagles. Ridgway (1889) listed the bald eagle as a "summer resident of general distribution." The eagle was considered a "more or less common" bird along the larger water courses. Historically, the bottomlands near the confluence of the Missouri, Ohio, and Mississippi rivers were major nesting areas for bald eagles (U. S. Fish and Wildlife Service 1986), and the large rivers and wetlands in and adjoining Illinois served as important winter habitat.

Declines in the continental population—caused by factors such as habitat destruction, illegal shooting, secondary lead poisoning, increasing human use of formerly remote areas, and, more recently, pesticide contamination that resulted in poor reproduction—have been reflected in the small numbers of bald eagles observed in Illinois from the late 1800s until the mid-1900s (Evans 1982). Postupalsky (1971) reported reproductive failure of two populations of bald eagles in Ontario associated with decreased eggshell thickness and residues in eggs of DDE, PCB, dieldrin, and mercury. These toxic chemicals caused one population to decline at a rate of 14–15% per year. However, with legal protection and the prohibition of certain pesticides, the nationwide number of bald eagles censused dramatically increased after the late 1970s and reached 13,869 in 1981 and 13,574 in 1990 (G.W. Kruse, Illinois Department of Conservation, personal communication). There were between two and four bald eagle nests documented in Illinois between 1978 and 1987. In 1992, 17 bald eagle nests were recorded in Illinois, and 16 eaglets successfully fledged.

Currently, the Mississippi River valley from southern Minnesota to southern Illinois is an important winter area for the endangered bald eagle (U.S. Fish and Wildlife Service 1986). Illinois, Missouri, and Arkansas host several hundred bald eagles each winter (U.S. Fish and Wildlife Service 1986). Millsap (1986) found that over 95% of the bald eagles observed during the 1979 to 1982 midwinter surveys occurred west of a line from Lake Michigan to the Mississippi delta and that more than 30% of the sightings occurred along and adjacent to the Mississippi, Illinois, and Missouri rivers.

Although nesting of bald eagles in Illinois is now a rare occurrence, large numbers of eagles still winter in the state and concentrate along the large rivers. Aerial censuses conducted by the Illinois Natural History Survey during early January from 1957 to 1993 along the floodplains of the Illinois River and the central section of the Mississippi River bordering Illinois from Alton to Rock Island demonstrate the recovery of the bald eagle in North America (Figure 59). A total of 1,211 bald eagles were inventoried along these two river floodplains in January 1990, a noticeable increase from the low numbers present during the late 1960s.

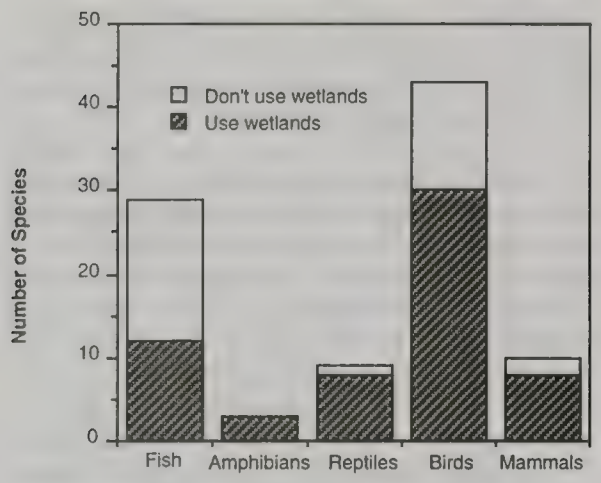

Figure 54. Proportion of endangered and threatened vertebrate species in Illinois that are strongly associated with wetlands.

The number of bald eagles observed during the Illinois Natural History Survey inventories has decreased since 1990, but this decline has been a result of weather-related dispersion of the birds and does not reflect a population decline. The Illinois component of the Midwinter Bald Eagle Survey conducted by the National Wildlife Federation documented 1,539 wintering bald eagles in Illinois in 1990, 1,864 in 1991, and 2,025 in 1992.

Double-crested Cormorants. Ridgway (1895) described the double-crested cormorant as a transient visitor in Illinois, arriving from the northern breeding areas in September and October and returning from their southern wintering areas along the Gulf Coast in March and April. The continental numbers of double-crested cormorants dramatically declined in the mid-1900s. Postupalsky (1971) reported that residues of DDE, PCB, dieldrin, and mercury were associated with eggshell thinning and reduced reproduction of double-crested cormorants in Ontario. Postupalsky (1971) stated that cormorants were declining in number throughout the Great Lakes area.

Since the early 1980s and more than a decade after the ban on DDT, cormorant populations have increased nearly 7% annually (Anonymous 1992). Double-crested cormorants have rebounded from a nationwide population of several thousand in the mid-1970s to approximately 235,000. This bird was nearly placed on the federal endangered species list in the late 1960s but now has become a nuisance to some aquaculturists and sport fishermen (Smith and Drieband 1991).

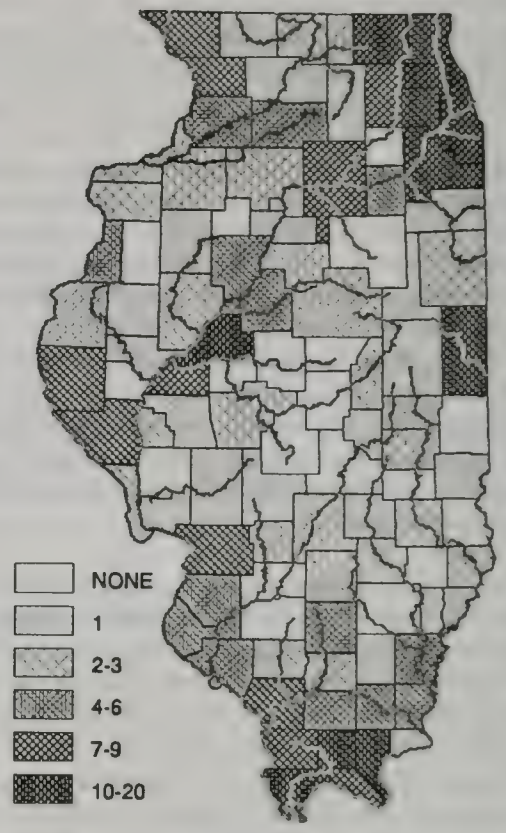

Figure 55. The number of threatened and endangered vertebrate species dependent upon wetlands in each county in Illinois, 1980 to the present.

In Illinois, Lake Renwick and Bakers Lake in the northeastern part of the state host nesting populations of double-crested cormorants. These birds, which nest in association with heron colonies, are on the state's endangered species list. Other nesting sites include Carroll County on the Mississippi River, Putnam and Peoria counties along the Illinois River, and Rend Lake in southern Illinois (Bohlen 1989).

The peak numbers of double-crested cormorants recorded in the Illinois River and Central Mississippi River valleys during aerial inventories conducted by Illinois Natural History Survey during fall migration from 1966 to 1992 demonstrate the upward trend in the North American population of this species (Figure 60). The fall inventories documented fewer than 100 double-crested cormorants in both of these river valleys from 1966 to 1973. However, 5,195 double-crested cormorants were observed in the Illinois Valley in the fall of 1992, and 1,515 were recorded in the central Mississippi River region in 1986.

Table 8. Status and habitats of the 30 Illinois endangered and threatened bird species that depend on or are strongly associated with wetlands.

Species	Status[a]	Shallow-water[b] wetland	Deep-water[c] wetland	Floodplain forest	Other[d]
Pied-billed grebe	E	X	--	--	--
Double-crested cormorant	E	--	X	X	--
American bittern	E	X	--	--	X
Least bittern	E	X	--	--	--
Great egret	E	X	--	X	X
Snowy egret	E	X	--	X	X
Little blue heron	E	X	--	X	X
Black-crowned night-heron	E	X	--	X	X
Osprey	E	--	X	X	--
Mississippi kite	E	X	--	X	X
Bald eagle	E*	X	X	X	X
Northern harrier	E	X	--	--	X
Red-shouldered hawk	E	X	--	X	X
Yellow rail	E	X	--	--	X
Black rail	E	X	--	--	X
Purple gallinule	E	X	X	--	--
Common moorhen	T	X	X	--	--
Sandhill crane	E	X	--	--	X
Piping plover	E*	--	--	--	X
Wilson's phalarope	E	X	--	--	X
Common tern	E	X	X	--	X
Forster's tern	E	X	X	--	--
Least tern	E*	X	X	--	X
Black tern	E	X	X	--	--
Short-eared owl	E	X	--	--	X
Brown creeper	T	--	--	X	--
Veery	T	X	--	X	--
Swainson's warbler	E	X	--	X	--
Henslow's sparrow	T	--	--	--	X
Yellow-headed blackbird	E	X		--	--

[a] Status = E = state-listed endangered species; T = state-listed threatened species; E* = federally listed endangered species.
[b] Shallow-water wetland = water ≤ 2 ft deep.
[c] Deep-water wetland = water > 2 ft deep.
[d] Other = sedge meadows, wet prairie, mudflats, sandbars, etc.

Mammals. Eight of the 10 endangered and threatened mammal species in Illinois use wetlands. These include two federally endangered species, the Indiana bat and gray bat, and two federal candidate species, the southeastern bat and Rafinesque's big-eared bat (U.S. Fish and Wildlife Service 1991). The Indiana bat hibernates in caves or mines, but its summer roosts and maternity colonies are usually under the exfoliating bark of trees (Humphrey et al. 1977). In Illinois, roost trees used by Indiana bats have been found in both floodplain and upland forest, and these bats may preferentially feed in floodplain forests (Gardner et al. 1990, 1991). The gray bat uses caves year-round, but forages in floodplain forests (La Val et al. 1977). The southeastern bat typically roosts in caves or mines, but a maternity colony was discovered in the hollow base of a tupelo gum in Little Black Slough in Johnson County (Gardner et al. 1992). Rafinesque's big-eared bats were also found roosting in a tupelo gum in this swamp (Gardner et al. 1992). Recent records for southeastern and big-eared bats along the Cache River and near Horseshoe Lake in Alexander County indicated the importance of forested wetlands as foraging habitat (Gardner et al. 1992). The southeastern and Rafinesque's big-eared bats occur only in the southernmost counties of Illinois, which lie at the edge of their ranges (Hoffmeister 1989).

The marsh rice rat is semi-aquatic and inhabits coastal marshes, freshwater marshes, wet meadows, and swamps (Wolfe 1982). In Illinois, this species has commonly been found in areas with herbaceous

Figure 56. The great egret, which typically nests in floodplain forests but prefers to forage in shallow-water wetlands. (Photo taken at Lake Renwick Heron Colony, Will County, by Joe Milosevich.)

wetland vegetation, including lake margins and roadside ditches (Hofmann et al. 1990). The golden mouse is arboreal and occurs in shrubby or wooded areas with a dense, tangled understory of vines, in canebrakes, and along the edges of swamps (Linzey and Packard 1977). These two rodents are limited to the southern portion of Illinois.

The main population of river otters in Illinois inhabits the backwaters of the Mississippi River and adjacent floodplain forests north of Rock Island; another population may be located at Little Black Slough (Anderson and Woolf 1984). The bobcat requires large tracts of relatively undisturbed habitat that includes upland forest, wooded bluffs, open fields, bottomland forest, and swamps (Hoffmeister 1989).

Amphibians. All three species of amphibians that are listed as endangered or threatened in Illinois depend upon wetland habitats (Herkert 1992). The silvery salamander, a unisexual polyploid species, was discovered in Illinois in 1973, and its only native population occurs at Middle Fork Woods Nature Preserve in Vermilion County (Morris 1974, Herkert 1992). These animals inhabit a wooded upland and ravine but breed in a single vernal pool (Herkert 1992). The dusky salamander, whose range extends only into the southernmost portion of Illinois, inhabits seeps, springs, and rocky headwater streams (Brandon and Huheey 1979). The Illinois chorus frog is a fossorial species that inhabits open sandy areas in floodplains, such as the sand prairies along the Illinois River (Axtell and Haskell 1977). It depends upon ponds, marshes, flooded depressions in fields, and roadside ditches for

Figure 57. Counties in which nesting black terns were found before and after 1980.

breeding (Brown and Rose 1988). Because of its specific habitat requirements, the range of the Illinois chorus frog probably has always been limited to its present extent (Herkert 1992).

Reptiles. Nine species of reptiles, three turtles and six snakes, are listed as endangered or threatened in Illinois (Herkert 1992). Seven of these species use wetland habitats (Smith 1961; R.A. Brandon, Southern Illinois University, personal communication). The spotted turtle inhabits sedge meadows in northeastern Illinois (Herkert 1992); elsewhere, it also occurs in ponds, bogs, and swamps (Conant and Collins 1991). Illinois lies at the western edge of the range of the spotted turtle, and it has been recorded in only Cook and Will counties (Smith 1961). The original spotted turtle colonies were presumably lost to urbanization, and the species is now restricted to Will County (Herkert 1992). The Illinois mud turtle is largely aquatic and occurs in sandy areas interspersed with permanent or semi-permanent ponds or sloughs (Smith 1961). Illinois mud turtle populations are disjunct from the main range of this more western species and are

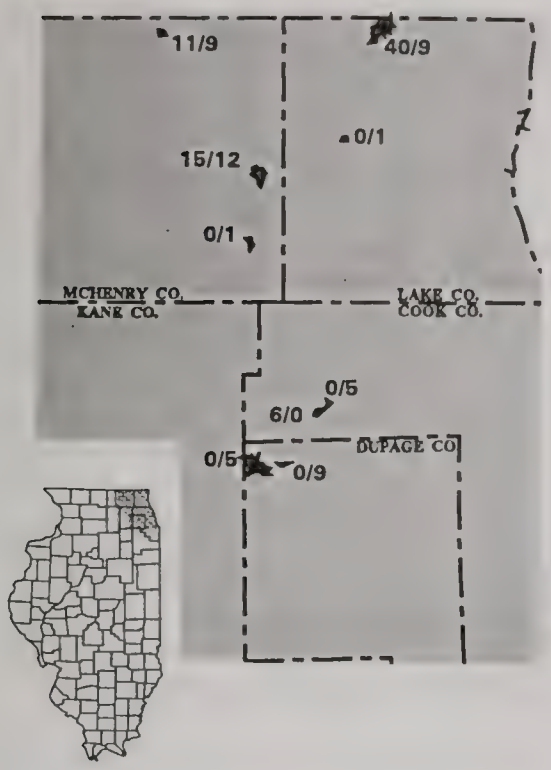

Figure 58. Black tern nesting locations in northeastern Illinois, 1980 to 1989. Before 1985 this species had 77 nests in 5 wetlands, and after 1985 it had 50 nests in 8 wetlands. (Shown as pre-1985/post-1985) Source: Heidorn et al. 1991.

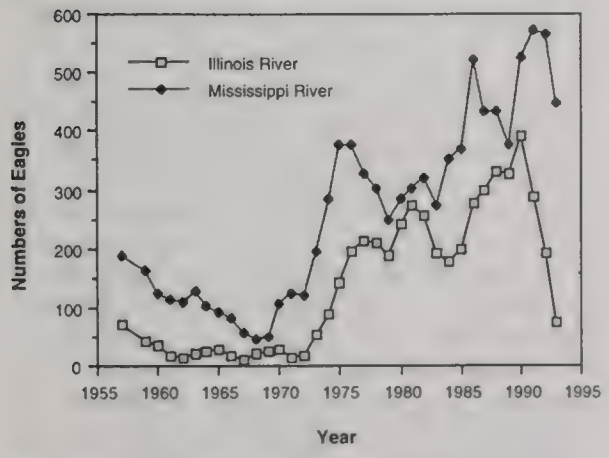

Figure 59. Number of bald eagles (3-year moving average) aerially inventoried by the Illinois Natural History Survey in the Illinois and central Mississippi River regions during the annual Midwinter Survey, 1955, 1958 to 1993.

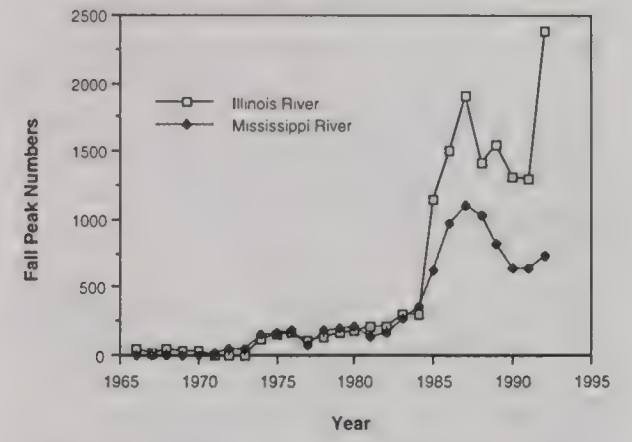

Figure 60. Peak numbers (3-year moving average) of double-crested cormorants aerially inventoried by the Illinois Natural History Survey in the Illinois and central Mississippi River regions during fall, 1966 to 1992.

restricted to sand areas in northwestern and west-central portions of the state (Smith 1961, Herkert 1992). Mud turtle populations have declined over the past 30 years as a result of human alteration of sand areas and the draining of ponds and sloughs. Optimal habitat for the river cooter appears to be heavily vegetated sloughs and oxbows on the floodplains of large rivers (Moll and Morris 1991). Although always considered rare, the river cooter, currently known from only four Illinois counties, once ranged more widely along the Mississippi, Ohio, and Wabash rivers (Smith 1961, Herkert 1992) (Figure 61). The reduction of the river cooter's range has probably been caused by the draining of swamps and oxbows and by channelization (Herkert 1992).

The green water snake and broad-banded water snake inhabit swamps, marshes, and river sloughs (Conant and Collins 1991). Both species presumably have always been limited to the southernmost portion of Illinois (Smith 1961), but the number of known localities for the green water snake has declined (Smith 1961, Herkert 1992) and the broad-banded water snake may be extirpated from the state (Herkert 1992). The eastern ribbon snake is semi-aquatic and occurs in swamps, marshes, ponds, and streams (Conant and Collins 1991). Illinois lies at the edge of this species' range; recent records are limited to four southern counties, but the species was formerly known from an additional two counties in southeastern Illinois (Herkert 1992). Although the great plains rat snake is typically an upland species that inhabits rocky wooded

hillsides, it occurs at Kidd Lake Marsh in Monroe County (R.A. Brandon, Southern Illinois University, personal communication). The range of this species barely extends into western Illinois (Smith 1961); once known to occur along the Mississippi River bluffs from Jersey to Randolph counties, it has recently been reported in only Monroe and Randolph counties (Herkert 1992).

Fish. Twelve of the 29 endangered and threatened fish species in Illinois occur in wetlands or use them for spawning (Smith 1979; Page and Burr 1991; L.M. Page, Illinois Natural History Survey, personal communication). The alligator gar is an inhabitant of swamps, bayous, and lakes as well as sluggish pools and backwaters of large rivers (Page and Burr 1991). The cypress minnow occurs in swamps, cypress-lined oxbow lakes, and sluggish backwaters of streams (Smith 1979, Page and Burr 1991). The habitat of the bluehead shiner includes backwaters, oxbows, and sluggish pools (Page and Burr 1991); in Illinois it has been found primarily along the vegetated margins of Wolf Lake in Union County (Burr and Warren 1986). The spotted sunfish and bantam sunfish inhabit swamps and heavily vegetated ponds, lakes, and sloughs (Smith 1979, Page and Burr 1991). The Iowa darter occurs in well-vegetated lakes, sloughs, and low-gradient streams (Smith 1979). The larval stage of the least brook lamprey lives in spring-fed wetlands, quiet pools, and backwaters of streams, although the adults occur in clear riffles and runs of streams and small rivers (Page and Burr 1991). In addition, five species that are inhabitants of lakes or streams require quiet areas with dense emergent vegetation for spawning and are, therefore, included as wetland species (L.M. Page, Illinois Natural History Survey, personal communication). These are the banded killifish, pugnose shiner, ironcolor shiner, blackchin shiner, and blacknose shiner.

Comparing post-1950 records to pre-1905 records, Smith (1971) concluded that drainage of natural lakes, marshes, swamps, and sloughs associated with large rivers in Illinois had resulted in range reductions for 13 native fish species, including the following wetland species that have since been listed as endangered or threatened: banded killifish, pugnose shiner, blackchin shiner, blacknose shiner, spotted sunfish, bantam sunfish, and Iowa darter. According to post-1980 records, the ranges of some of these species appear to have been reduced further (Herkert 1992). The blacknose shiner, for example, was recorded from numerous locations throughout the northern two-thirds of Illinois prior to 1905 but from only eight counties during the 1950s and 1960s (Smith 1971). Since 1980, this species has been found only in Lake County (Herkert 1992).

The cypress minnow has probably always been limited to southern Illinois; even so, its range has been drastically reduced. Once collected (sometimes in large numbers) from seven locations in the Big Muddy River, Clear Creek, Cache River, and Horseshoe Lake drainages, this species now occurs only at two locations along the Cache River and, perhaps, in Horseshoe Lake (Warren and Burr 1989) (Figure 62). A prime factor in the range reduction of the cypress minnow has been the drainage of wetlands for agriculture (Warren and Burr 1989).

Two of the endangered and threatened wetland species of fish, the alligator gar and bluehead shiner, may already be extirpated from the state (Burr 1991). The alligator gar had been reported from the lower Mississippi, Big Muddy, Ohio, Wabash, Kaskaskia, and Illinois rivers and Horseshoe Lake in Alexander

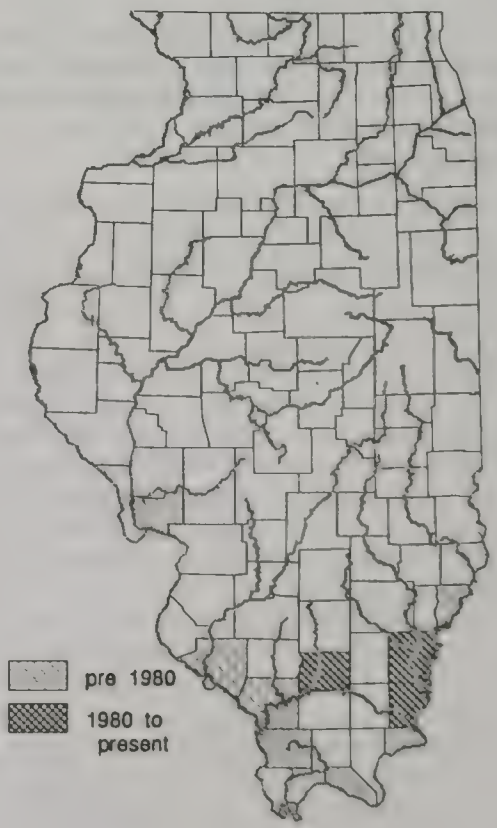

Figure 61. Distribution of the state-endangered river cooter in Illinois before and after 1980. Source: Herkert 1992.

County (Smith 1979), but it has not been found in Illinois since 1965 (Burr 1991). The major cause of its loss (or decline) has been channelization and impoundment of rivers, modifications that eliminated much of their quiet backwater areas. The bluehead shiner, known only from springs at Pine Hills, Otter Pond, and Wolf Lake in Union County, has not been found since a chemical spill in Wolf Lake in 1974 (Burr and Warren 1986, Burr 1991).

Invertebrates. Fifty-one invertebrates are listed as endangered or threatened in Illinois, including one snail, 33 freshwater mussels, 11 crustaceans, and five insects. Of these, only one mussel, two crustaceans (amphipods), and one insect are considered wetland species. The pondhorn mussel inhabits ponds, sloughs, and lakes (Herkert 1992). Two species of amphipods occur in shallow groundwater habitats such as seeps, springs, caves, and subsurface cavities in limestone and are known only from extreme southeastern Illinois (Herkert 1992). The Hine's emerald dragonfly inhabits distinctive marsh communities in northeastern Illinois.

Hine's (Ohio) emerald dragonfly is named after its distinctive bright green eyes. Its strong flying ability as an adult enables it to capture and devour smaller insects, including pests such as mosquitoes and biting flies, on the wing. The dragonfly's connection to a rare and localized type of wetland has threatened its populations. The species is now listed as endangered in the state of Illinois, is a candidate for federal listing by the United States Fish and Wildlife Service as endangered or threatened, and is listed as endangered by the International Union for the Conservation of Nature (U.S. Fish and Wildlife Service 1990, Cashatt 1991, Herkert 1992). Hine's emerald dragonflies are currently restricted to a few sites in Illinois and Door County, Wisconsin (Cashatt and Vogt 1992). In Illinois, the dragonflies are found only in specific habitats in the Des Plaines River watershed where calcareous water emerges from the contact zone between the overlying glacial till and the limestone bedrock and collects in shallow cattail marshes, wet meadows, or small streams (Figure 63) (Cashatt and Vogt 1990, Cashatt 1991, Cashatt et al. 1992). The breeding habitat requirements for this dragonfly are restrictive because the immature stage requires clean water in which to develop. The largest threat to the continued existence of this dragonfly is habitat destruction and fragmentation caused by urban and industrial development. The Illinois sites are currently being threatened by a petroleum refinery, a sewage treatment plant, rock quarries, an electrical power plant, an asphalt plant, and a highway project (Cashatt and Vogt 1992).

ONGOING WETLAND CHANGES

Annual Rate of Loss

Dahl (1990) estimated that in the conterminous United States at the time of Colonial America there were 221 million acres (89.5 million ha) of wetlands. The estimate of wetlands in the contiguous 48 states in the mid-1970s was 105.9 million acres (42.9 million ha) (Dahl and Johnson 1991). Between the mid-1950s and the mid-1970s, about 11 million acres (4.5 million ha) of wetlands were lost while 2 million new acres (810,000 ha) were created (Tiner 1984). Of the remaining wetlands, palustrine wetlands represented 94% (Frayer et al. 1983).

Despite some slight gains in wetlands, principally as a result of construction of ponds, reservoirs, irrigation projects, and restoration, the recent nationwide trend in wetland acreage has been clearly downward. The average rate of wetland loss from the mid-1950s to the mid-1970s was 458,000 acres (185,350 ha) per year,

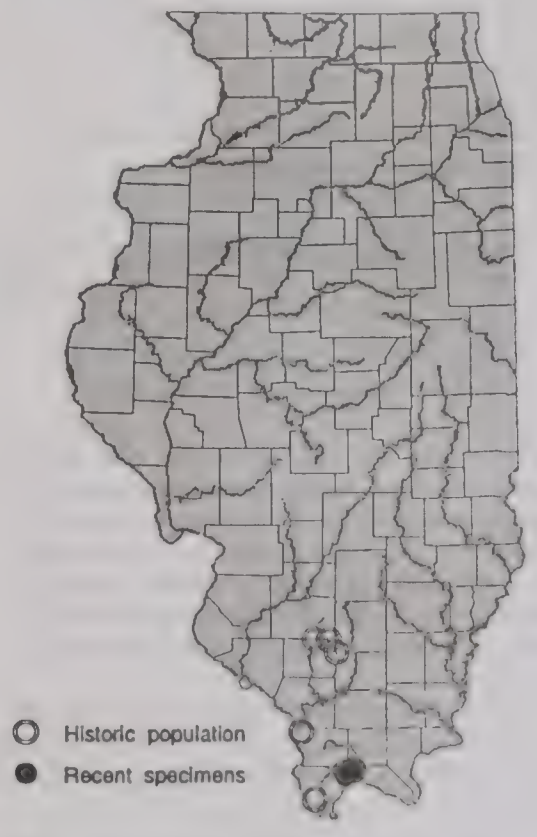

Figure 62. Locations of historic populations and recent specimens of the state-endangered cypress minnow in Illinois. Source: Warren and Burr 1989.

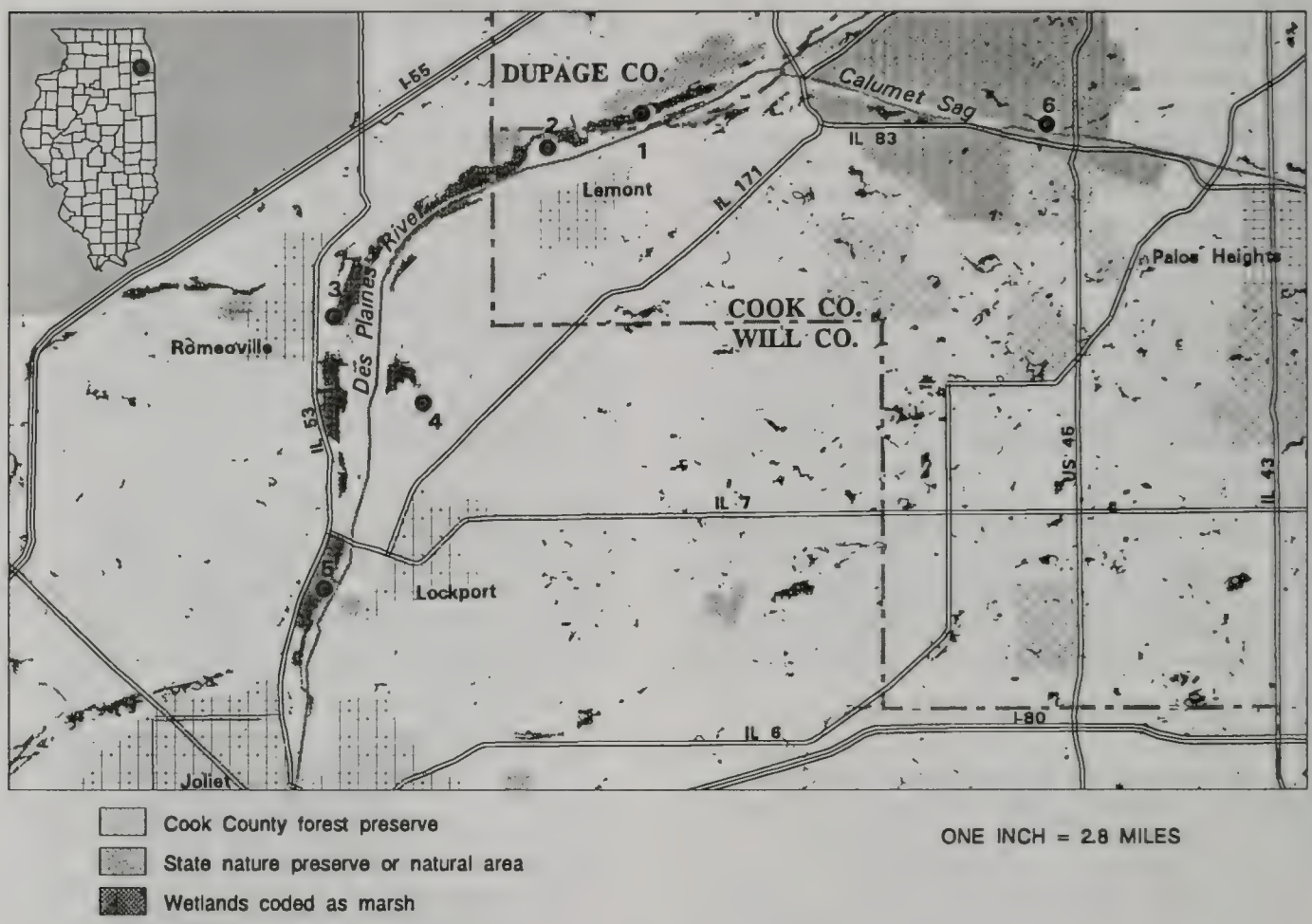

Figure 63. Sites in Illinois where Hine's emerald dragonfly occurs (1–Waterfall Glen Forest Preserve, 2–Black Partridge Woods Nature Preserve and environs, 3–Romeoville Prairie Nature Preserve, 4–Long Run Seep Nature Preserve, 5–Lockport Prairie Nature Preserve, 6–McMahon Woods, Palos Park). Source: Cashatt and Vogt 1990, Cashatt at al. 1992.

96% (440,000 acres or 178,066 ha) of which represented losses of palustrine wetlands (Frayer et al. 1983). Drainage for agricultural development was responsible for 87% of the recent wetland losses; urban development accounted for 8% and other development, 5%. Agriculture affected forested and emergent wetlands more than other types during this 20-year span (Tiner 1984).

By the mid-1980s, wetlands occupied about 5% of the land area of the conterminous United States (Dahl and Johnson 1991). There were 103.3 million acres (41.8 million ha) of wetlands, 97.8 million acres (39.6 million ha) of freshwater wetlands, and 5.5 million acres (2.2 million ha) of coastal wetlands. Over 2.6 million acres (1.05 million ha) of wetlands were lost between the mid-1970s and the mid-1980s, an average annual loss of approximately 290,000 acres per year (117,361 ha). This rate of loss was less than the rate of 458,000 acres per year (185,350 ha) found between the mid-1950s and the mid-1970s (Dahl and Johnson 1991). Conversion of wetlands to agricultural land use decreased from 87% for the mid-1950s to the mid-1970s to 54% during the mid-1970s to the mid-1980s. The lower 48 states lost an estimated 53% of their original wetlands by the 1980s. Twenty-two states have lost at least 50% of their original wetlands, and 10 states in the Mississippi Flyway, including Illinois, Arkansas, Indiana, Iowa, Kentucky, Missouri, and Ohio, have lost 70% or more of their original wetland acreage (Dahl 1990).

Rates of wetland loss are difficult to quantify, especially with ever- changing federal and state programs

and policies. Within this context, identifying the exact rate of loss for wetlands in Illinois is formidable. However, an approximation can be derived from the national trend, for which more data are available. According to the U.S. Fish and Wildlife Service, the national rate of wetland loss was approximately 0.5% annually during the mid-1950s to mid-1970s. A random survey of 10 county agricultural and environmental resource professionals in Illinois in 1990 indicated that the national rate of 0.5% annual loss of wetlands was consistent with losses they observed in their respective counties. The southern tip of Illinois appeared to have a loss rate well above the national average, the northwest corner of the state appeared to have a loss rate at or above the national average, and the rest of the state had a loss rate at or below the national average (T. Dahl, U.S. Department of the Interior, personal communication). This trend is based upon very limited information and is not statistically valid. However, it does indicate that wetland losses continue in Illinois, with some areas experiencing higher loss rates than others.

Agricultural Loss

An important factor in the demise of wetland resources in Illinois was the implementation of drainage and levee districts. The passage of a series of Swamp Lands Acts in 1849, 1850, and 1860 resulted in the destruction of many wetlands in the United States. With these Acts, Congress gave 65 million acres (26.3 million ha) of wetlands to 15 states and urged them to reclaim the land for agriculture and sell it (Steinhart 1990). The Swamp Lands Act of 1850 included Illinois. Under this Act, Illinois deeded the wetlands to the counties (Lockart 1980). In 1852, the Illinois General Assembly enacted legislation giving county courts jurisdiction over wetlands, and any funds obtained from the sale of these lands were to be primarily used for drainage projects (Lockart 1980). By June 1906, Illinois had claimed almost 4 million acres (1.6 million ha) of "swamp land" from the federal government, and approximately 82 million acres (33.2 million ha) were claimed by the 16 states named in the Swamp Lands Acts (Wright 1907).

Although the first drainage district was organized before 1818, only 163,000 acres (65,965 ha) were in drainage districts in Illinois by 1879 (Illinois Tax Commission 1941). By 1880, the largest part of the agriculturally productive lands of Illinois had been tilled, but poor natural drainage in much of the low, flat areas hampered production. Following the pattern developed in other states, Illinois created quasi-governmental units, known as drainage districts, which had many powers, including the power of eminent domain, under the Levee Act of 1879 and the Farm Drainage Act of 1885 (Lockart 1980, Thompson 1988). The Levee Act allowed the formation of drainage and levee districts to facilitate the needs of landowners in the fertile bottomlands, whereas the Farm Drainage Act allowed the formation of drainage districts to the benefit of owners of wet upland soils (Thompson 1988). Organization of districts proceeded rapidly, with more than 1.5 million acres (0.6 million ha) incorporated into new districts in Illinois during the 1880s (Illinois Tax Commission 1941).

In Illinois, 5,454,000 acres (2,207,204 ha) of the state's approximately 35.9 million acres (14.5 million ha) had been drained by organized districts by 1937, and an additional 4 million acres (1.6 million ha) had been drained by private enterprise (Illinois Tax Commission 1941, Sanderson et al. 1979) (Figure 64). By 1978, the total area of lands drained for agriculture in Illinois had increased slightly to over 9.7 million acres (3.9 million ha), or approximately 27% of the area of the state (U.S. Department of Commerce 1978). Drainage of wetlands in Illinois destroyed many valuable waterfowl areas, including over 200,000 acres (80,939 ha) of the Illinois River valley and over 400,000 acres (161,878 ha) of the Mississippi River floodplain, primarily from Rock Island to Cairo (Lockart 1980). The Sny Island Levee District alone incorporates over 100,000 acres (40,469 ha) in Pike, Adams, and Calhoun counties (Lockart 1980). Other river floodplains also were affected, including 144,000 acres (58,276 ha) leveed and drained along the Cache, Ohio, and Wabash rivers (Lockart 1980).

By 1905 in the United States, an estimated 30 million acres (12.1 million ha) were drained (Donnan and Sutton 1960). Between 1940 and 1950, an estimated 1.5 million acres (0.6 million ha) a year were added nationwide to organized drainage enterprises (Stefferud 1958). There were more than 102 million acres (41.3 million ha) in organized drainage enterprises in 1960 in the United States (Donnan and Sutton 1960). In addition, an estimated 50 million acres (20.2 million ha) of farmland were drained by private or farm drainage, resulting in a total of 153 million acres (61.9 million ha) of artificially drained land (Stefferud 1958). Between 1940 and 1960, the U.S. Department of Agriculture subsidized the drainage of approximately 60 million additional acres (24.3 million ha) for agricultural purposes (Steinhart 1990). Artificially drained agricultural land under organized enterprises in 1980 totaled approximately 107.5 million acres (43.5 million ha) (Dahl 1990).

Urban Loss

The loss and modification of wetlands as a result of urbanization is apparent in the nation and in Illinois. From the mid-1950s to the mid-1970s, urban development accounted for 8% of the wetland losses in the contiguous 48 states (Frayer et al. 1983). The loss of wetlands to urbanization continued in the United States between the mid-1970s and the mid-1980s (Dahl and Johnson 1991). In northeast Illinois, the Chicago District of the U.S. Army Corps of Engineers issued 372 wetland fill permits in 1992, compared with nine in 1983 (Dreher et al. 1988) (Figure 65). Most permit applications regarding wetlands and stream modification in the region of the Chicago District were granted, and the number of applications ranged from about 50 to 90 per year from 1982 to 1985 (Figure 66).

FACTORS AFFECTING WETLANDS

Although the loss of wetlands is of monumental importance, the biological, chemical, and physical degradation of wetlands by humans and the resultant decline in productivity and diversity of those wetlands remaining are also significant. Wetlands have been affected by many factors, including alteration of natural hydrological regimes (i.e., drainage, dams, channelization, reservoirs), agriculture, urbanization, and nonpoint pollution, especially sedimentation.

Sedimentation

Erosion is responsible for removing 201 million tons (182 million metric tons) of soil each year in Illinois (Illinois Department of Agriculture 1992). Approximately 35% of the 32 million acres (13 million ha) of rural land in Illinois requires some form of soil erosion control treatment. However, in 1990, Illinois led the nation in the number of acres of cropland planted with conservation tillage systems, which were used on 37.3% of the state's cropland. Illinois also led the country in no-till planting (2.6 million acres; 1.05 million ha) in 1990 (Illinois Department of Agriculture 1992).

Nevertheless, sedimentation has been a major factor in the degradation of wetlands, especially in the upper Midwest. Illinois, Iowa, Minnesota, Missouri, and Wisconsin together represent only about 15% of the hydrologic area of the entire Mississippi River basin but produce about 40% of all the sediment originating from cropland in the basin (Peterson 1991). Furthermore, about 55% of the land in these five states is

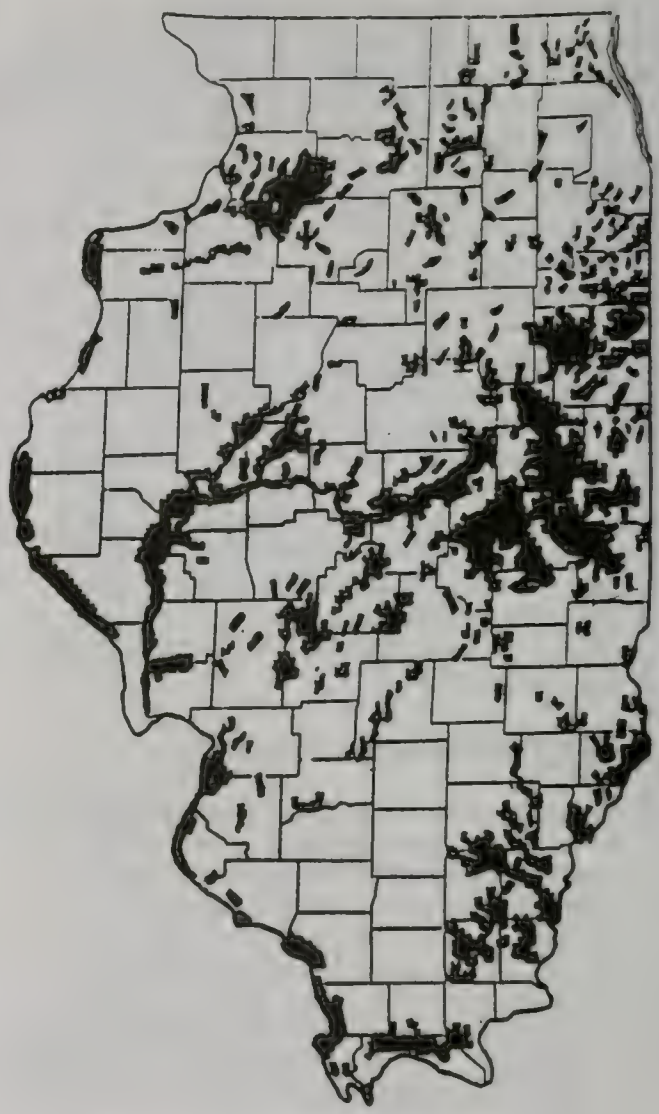

Figure 64. Organized drainage and levee districts in Illinois prior to 1941 (Illinois Tax Commission 1941).

cropland, as compared with a national average of 18% (Peterson 1991). Although erosion rates have been reduced in recent years, the rate of erosion in these five states was 32% above the national average (Peterson 1991).

Sedimentation is the primary factor causing degradation of many wetlands in agricultural areas. In Illinois, the proliferation of land planted in row crops, principally soybeans, in the past half century was conducive to increased rates of sedimentation in the Illinois River valley (Bellrose et al. 1983). The increase in the amount of land planted in row crops, which do not protect the soil from wind and water erosion as well as

small grains (wheat) and permanent cover (pasture, hay crops), was accompanied by the common practice of fall tillage with the moldboard plow. Harvested cornfields subjected to tillage with the moldboard plow in Illinois left only about 5% of crop residue and virtually no waste grain for wildlife (Warner et al. 1985). Consequently, with these changes, rates of sedimentation greatly increased.

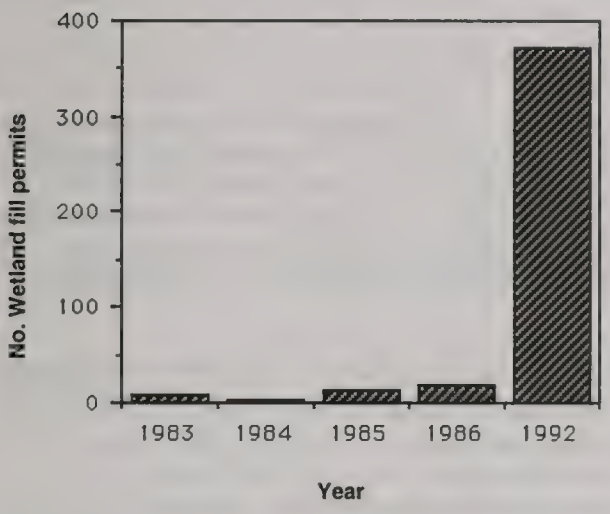

Figure 65. The number of wetland fill permits issued by the Chicago District of the Corps of Engineers, 1983 to 1986 and 1992. Source: Dreher et al. 1988.

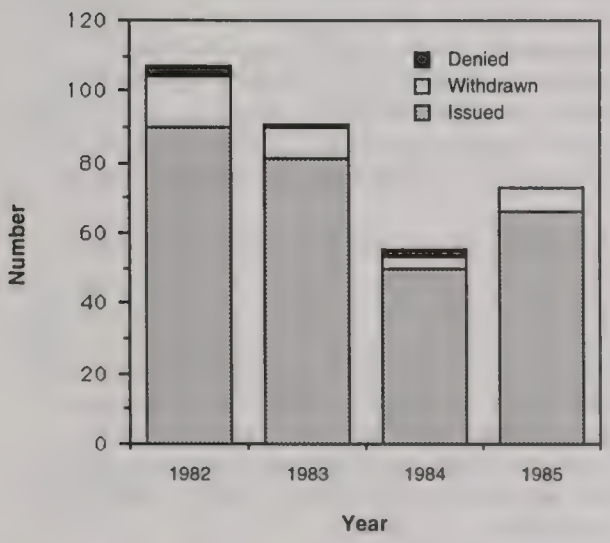

Figure 66. Permit decisions of the Chicago District of the Corps of Engineers, 1982 to 1985. Source: Dreher et al. 1988.

In the 1970s, the Illinois River received an estimated 27.6 million tons (25 million metric tons) of sediment per year; approximately 15.4 million tons (14 million metric tons) of sediment was deposited in the valley, and the remainder was transported to the Mississippi River (Lee and Stahl 1976). Sedimentation affects wetlands by deposition, by increasing turbidity, which reduces light penetration necessary for photosynthesis in submerged aquatic vegetation, and by creating soft bottoms, which preclude the ability of wetland plants to remain rooted (Bellrose et al. 1979, 1983; Havera and Bellrose 1985). With the loss of aquatic plants as a result of sedimentation and other factors, the integrity of the wetland systems and the quality of waterfowl habitat in the Illinois Valley were significantly diminished (Havera and Bellrose 1985). The "early warning" indicators of the degrading effects of sedimentation on aquatic habitats are now appearing in the upper Mississippi River.

WETLAND PROGRAMS

There are numerous federal, state, local, and private programs that address wetlands and wetland-related issues in Illinois (Table 9). These programs include both regulatory and nonregulatory mechanisms, such as acquisition, planning, education, restoration, and technical assistance, and vary in their relative importance as wetland protection mechanisms. Several programs have important effects, both positive and negative, on wetlands in Illinois.

Illinois has accomplished an important step in maintaining an adequate wetland base. The Interagency Wetland Policy Act, enacted in 1989, established a goal of no overall net loss of existing wetlands or their functional value in Illinois as a result of state and state-supported activities. This act also directs state agencies to preserve, enhance, and create wetlands in order to increase the quality and quantity of the state's wetland resource base.

WETLAND CREATION/RESTORATION

Federal and state governments have historically provided incentives to destroy wetlands. With increased knowledge and appreciation of the value of wetlands, however, a regulatory framework that emphasizes avoiding or minimizing impacts to wetlands is now in place, and the rate of wetland drainage and conversion has slowed. Furthermore, wetland restoration and creation activities have contributed to

ameliorating the effects of unavoidable loss in wetland acreage. At this time, however, many aspects of the concepts and methods for creating and restoring wetlands are unknown.

Simply defined, wetland restoration involves returning a disturbed or severely altered wetland to a state similar to its pre-existing condition. Much of the agricultural land in central Illinois, for example, includes ideal locations for restoration. This land often possesses a sufficient source of groundwater or surface water, favorable topography, wetland soil, and a reservoir of ungerminated seeds of wetland plants in the soil, and the land would revert to its former wetland state if field tiles were plugged and levees were removed.

Alternatively, wetland creation is the construction of a wetland in an area that historically did not support a wetland. Because the essential components of wetlands must be artificially produced in this process, created wetlands are less likely to replicate the functions and values of a natural wetland.

Wetlands are restored or created for both regulatory and nonregulatory purposes. In the regulatory context, many wetlands have been restored or created to compensate, or mitigate, for wetland losses permitted by the Corps of Engineers. The Corps usually requires mitigation as a condition for allowing certain activities, such as the dredge or fill of wetlands, that are restricted in Section 404 of the Clean Water Act. Nonregulatory purposes for restoration and creation include providing wildlife habitat and storm-water storage.

Examination of available information on wetlands restored or created as mitigation required under Section 404 regulations may suggest the direction of wetland restoration and creation overall. For example, in 1991, the Corps of Engineers received about 15,000 Section 404 permit applications nationwide. Approximately 10,000 permits were granted, 30% of the applications were withdrawn or qualified under a general permit, and 5% of the applications were denied.

Trends and patterns in Section 404 permit information were examined for Oregon for 1977 through 1987, for Washington for 1980 through 1986 (Kentula et al. 1992), and for Louisiana, Alabama, and Mississippi (Sifneos et al. 1992a) for 1982 through 1986, as well as for Texas and Arkansas (Sifneos et al. 1992b). In 13 counties in the South Florida Water Management District, projects examined were completed between 1987 and 1991 (Erwin 1991); in Wisconsin, 1988 data covering federal, state, and county permits were considered for seven counties (Ott 1990).

The fundamental element of any wetland restoration or creation project is the overall goal or intended purpose for the restored or created wetland. A goal of many of the created or restored wetlands considered in the aforementioned state studies was to replace functions lost from the destroyed wetlands. Wildlife and fisheries habitat, flood storage, and food chain support were common functions affected; however, these functions were not necessarily replaced in the created wetlands. Often, the functions of the original wetlands were unknown. Specified goals for about two-thirds of the permits examined in Florida were limited to acreage and desired habitat; 15% of the permits stated no goals. Fifty-six percent of the permits issued in Wisconsin fully complied with the requirements. Only 10% of the projects in Florida completely satisfied permit goals; another one-third partially fulfilled the requirements.

An obvious trend observed in these states was an increase in the number of permits issued. Also, the size of mitigation projects decreased over the period. In Oregon and Washington, more than 50% of wetlands created or destroyed were ≤ 1 acre (0.40 ha). In Louisiana, 63% of compensation wetlands and 59% of the wetlands affected were ≤ 12.5 acres (5.0 ha). Similar results were noted in Texas. In Florida, the size of created and restored wetlands varied by the type of project, ranging from 0.1 acre (0.04 ha) for a commercial project to 195.2 acres (79 ha) for an agricultural project. In Louisiana, 81% of the permits required compensation in area equal to the loss. The number of wetland acres destroyed and created in the states studied, based on available Section 404 permit information, is shown in Figure 67. Although some gain in the number of wetland acres occurred in Alabama, 89% of the increase resulted from one permit.

A greater number of wetlands discussed in the state reports were replaced in-kind (i.e., as the same wetland type) than out-of-kind. In-kind compensation generally resulted in the gain or maintenance of wetland acreage, but acreage decreased when compensation was out-of-kind. In some states, such as Wisconsin, many ponds were created when other types of wetlands were destroyed. Most of the destroyed and of the compensatory wetlands in the states studied were located in urban areas.

Details on Section 404 permits for a small part of Illinois have been recently compiled, and trends are

Table 9. Important federal, state, local, and private wetlands programs in Illinois (adapted from Havera 1992 and Hubbell et al. 1993).

Program	Mechanism	Effect	Description
Federal			
Executive Order #11990	Federal directive	Positive	Requires each federal agency to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in implementing agency responsibilities.
Farm Bill–Conservation Reserve Program	Acquisition, incentive-disincentive, management	Potential/ positive	Discourages landowners from farming highly erodible land for 10 or 15 years; requires a soil conservation plan to receive annual payments.
Farm Bill–Swampbuster	Incentive-disincentive	Potential/ positive	Discourages the conversion of wetlands on agricultural land by denying federal farm subsidies.
Migratory Bird Conservation Fund	Acquisition	Positive	Finances acquisition of land for the national wildlife refuge system. In addition, easements or fee-simple title can be acquired for wetlands for use as federal waterfowl production areas.
North American Waterfowl Management Plan	Acquisition, planning, funding, management	Positive	Provides funding for protection, enhancement, or restoration of wetlands that are important to waterfowl and other migratory birds.
North American Wetland Conservation Act	Acquisition, funding, management	Positive	States, private groups, or individuals can receive matching grants for wetland conservation projects if the projects further the goals of the North American Waterfowl Management Plan.
National Wetlands Inventory	Technical assistance	Neutral/ positive	Provides a detailed database of existing wetlands for research and other purposes. The Illinois portion was completed in the mid-1980s.
Pittman-Robertson Wildlife Restoration Act	Acquisition, funding, management, restoration	Positive	Provides for the acquisition, restoration, and management of land for wildlife, including wetlands.
Clean Water Act-Section 404	Regulation	Positive	Requires permits for regulation of non-point source discharges of dredged or fill material into wetlands.
Fish and Wildlife Private Lands Initiative	Management, restoration, incentive-disincentive, technical assistance	Positive	Encourages wetland restoration of converted or degraded wetlands on private lands.
Environmental Management Program	Management, funding	Positive	The Habitat Rehabilitation and Enhancement Project element of the Environmental Management Plan provides several million dollars for a minimum of 10 years to improve wetlands on public areas in the Upper Mississippi River System.
State			
Federal Clean Water Act–Section 314	Management	Positive	Identifies the condition of all publicly owned freshwater lakes. Also attempts to control pollution and restore water quality.
Federal Clean Water Act–Section 319	Management	Positive	Allows Illinois the authority to assess non-point water pollution sources and introduce management programs to control pollution.
Farmland Assessment Act	Incentive-disincentive	Potential/ positive	Allows farmers and landowners to receive property tax relief for wetlands and certain other habitats.
Illinois Drainage Code Act	Regulation	Negative	Provides broad drainage regulations for agricultural, sanitary, or mining purposes. Also organized the operation of drainage districts.

Program	Mechanism	Effect	Description
Illinois Endangered Species Act	Regulation	Potential/ positive	Provides protection for threatened and endangered species within Illinois.
Interagency Wetland Policy Act	Regulation	Positive	Promotes no overall net loss of wetlands or their functional value as a result of state-supported activities.
Natural Areas Fund	Acquisition	Positive	Provides for the acquisition and stewardship of natural areas, including wetlands.
Rivers, Lakes, and Streams Act	Regulation	Potential/ positive	Provides for some protection of wetlands in floodplains.
Soil and Water Conservation District Act–Section 22.02(a)	Acquisition	Potential/ positive	Land use changes within a county or municipality must be reviewed by the appropriate Soil and Water Conservation District.
State Migratory Waterfowl Fund	Acquisition	Positive	Provides funds for improvement of waterfowl habitat in Illinois and Canada and implementation of the North American Waterfowl Management Plan.
Wildlife Habitat Endowment Fund	Acquisition	Positive	Provides an endowment for the purpose of maintaining and acquiring high-quality wildlife habitat, including wetlands.
Local			
Local ordinances - critical habitat - subdivision - zoning	Regulation, planning, acquisition	Potential/ positive	Local ordinances can affect wetlands protection and management within the jurisdictional unit of government.
Parks and open space programs	Acquisition	Positive	Local government has the authority to acquire land as necessary. Land set aside for parks or open space can include wetlands or can provide protection for wetlands.
Stormwater management	Regulation	Potential/ positive	County codes allow for management and mitigation effects of urbanization on stormwater drainage in metropolitan counties controlled by the Northeastern Illinois Planning Commission.
Tax incentives–property and income	Incentive-disincentive	Potential/ positive	Tax incentives can benefit landowners who protect wetlands. Taxes can be reduced for certain land uses.
Water quality programs	Acquisition	Positive	Local units of government, through the municipal and county codes set forth by the state, have the right to institute water quality standards within their jurisdiction. These programs can protect wetlands by controlling degrading pollution sources.
Private			
Ducks Unlimited–M.A.R.S.H.	Acquisition	Positive	The primary focus is the development, restoration, and management of wetland areas for waterfowl habitat.
The Nature Conservancy	Acquisition	Positive	A national organization that preserves the diversity of land in the United States. The group also works with state agencies to identify ecologically significant areas.
Open lands projects	Acquisition, restoration, management	Positive	Wetland acquisition projects can provide good habitat while allowing private ownership. Private acquisition is often more expedient than governmental acquisition.

Program	Mechanism	Effect	Description
Property tax maintenance	Incentive-disincentive	Positive	Landowners can take certain tax deductions by participating in conservation programs that affect wetlands.
Regional plans-- Heartland Water Resouces Council	Planning	Positive	Heartland Water Resources Council is a not-for-profit venture on the Illinois River.
Special area plans - Cache River - Cypress Creek	Planning	Positive	Special area plans help manage natural resources within a specific area and provide for research and management efforts.

similar to those described in other states. The number of wetland acres lost during fiscal years 1991, 1992, and 1993 in the St. Louis District of the Corps of Engineers as a result of individual permits was 63.3 (25.6 ha), 58.4 (23.6 ha), and 100.2 (40.6 ha), respectively, while the number of acres gained was 218 (88.2 ha), 121.5 (49.2 ha), and 505.7 (204.7 ha), respectively (K. Meldrum, Regulatory Branch, St. Louis District, Corps of Engineers, personal communication). The number of nationwide #26 permits, which regulate discharges of dredged or fill material into headwaters and isolated waters, issued by the Chicago District of the Corps of Engineers has been increasing. Additionally, in the Chicago District, 379 Section 404 nationwide permits relating to wetlands were issued during fiscal year 1992, and 129 permits were issued during the first half of fiscal year 1993 (M. Machalek, Construction-Operations Division, Regulatory Branch, Chicago District, Corps of Engineers, personal communication). Permits were issued for the filling of 91 acres (36.8 ha) of wetlands in the Chicago District by March 1993; mitigation efforts have resulted in the creation of 93 acres of wetlands (37.6 ha). Also in the northeastern part of Illinois, the Illinois Department of Transportation has been responsible for affecting 30.7 wetland acres (12.4 ha) and creating nearly 70.5 acres of wetlands (28.5 ha) since 1989, and an additional 33.8 acres (13.7 ha) are currently under construction as compensation for loss of 20 acres (8.0 ha) (D. Niemann, Bureau of Programming, Illinois Department of Transportation, District 1, personal communication).

Wetlands have also been created and restored for nonregulatory purposes throughout Illinois for many years. Governmental agencies involved in this activity include the Illinois Department of Conservation and the U.S. Soil Conservation Service. The Department of Conservation has built wetlands for waterfowl management and wildlife habitat since the 1940s. Recent Department restoration and creation activity has occurred at Horseshoe Lake, Castle Rock, Moraine Hills, and Illinois Beach state parks. Other wetlands were developed in subimpoundments and associated areas as a consequence of the construction of reservoirs by the Corps of Engineers, primarily in the 1960s and 1970s. The U.S. Fish and Wildlife Service private lands initiative through the Partners for Wildlife Program, the North American Waterfowl Management Plan, and the 1985 and 1990 Farm Bills in conjunction with Illinois Department of Conservation have resulted in restoration of 73 wetlands in Illinois totaling 1,378 acres (558 ha) since 1987 and easements on an additional 28 sites totaling over 1,000 acres (405 ha) (Allen 1992).

Much of the wetland work by the Soil Conservation Service has been accomplished only recently or is still in a planning stage. Non-discharge-system wetlands constructed for water quality improvement have been a major focus and are important for treating both agricultural wastes and public water supplies. Two current projects include an experimental study on the upper Embarras River and a water quality improvement wetland for Lake Bloomington. A total of 421 acres (170 ha) of wildlife shallow ponds and 16,381 acres (6,632 ha) of bottomland wetlands and floodplain scour (where more than half of the area must be planted to trees) have been created in Illinois (G. Barickman, Soil Conservation Service, personal communication).

Even though the number of acres of restored and created wetlands appears to balance current wetland loss, most of these wetlands have been formally inspected only recently to determine whether they are actually fulfilling their intended purpose and functioning as natural wetlands. Wetland monitoring involves examining various components of the system, such as water quality, vegetation, invertebrates, fish, mammals, or birds. The extent to which these parameters meet the stated goals determines whether the restored or created wetland is successful or is progressing toward success. Monitoring also allows early detection of any problems

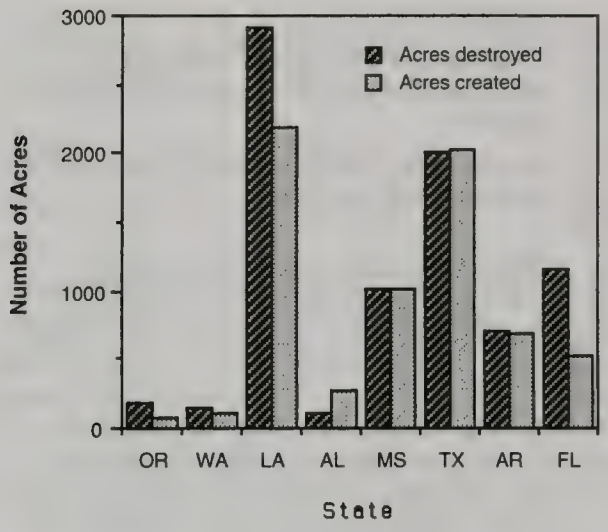

Figure 67. Number of wetland acres destroyed or created in various states, based on Section 404 permit information. Source: Erwin 1991, Kentula et al. 1992.

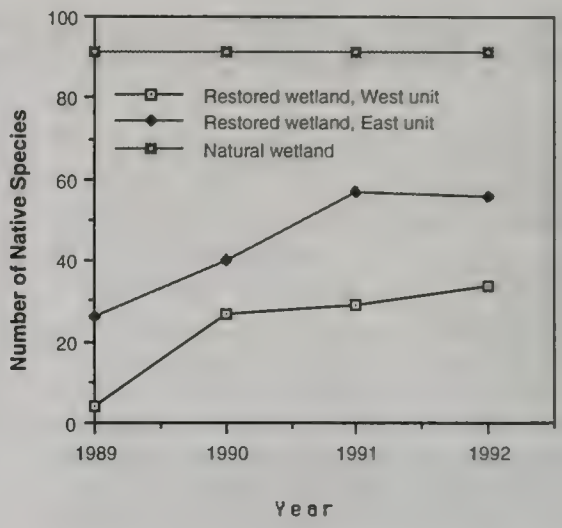

Figure 68. Number of native species present in two units of a restored wetland in Kane County, 1989 to 1992, compared to the number of native species in the original natural wetland. Source: Wilhelm and Wetstein 1992b.

that might occur, which subsequently can be addressed in a timely manner. This type of corrective management increases the likelihood that the wetland will function more like a natural wetland.

Monitoring of restored or created wetlands in various states for compliance with Section 404 often has been inadequate. In the Pacific Northwest (Kentula et al. 1992) and in Texas (Sifneos et al. 1992b), about half of the sites studied were visited at least once; however, there has been no indication that these wetlands were actually fulfilling their intended purpose. In Louisiana, only 10% of projects were inspected (Sifneos et al. 1992a), and in Arkansas no monitoring was required (Sifneos et al. 1992b). Monitoring was required in all but one of the 40 projects studied in Florida, but only 15 projects were monitored sufficiently, and 15 projects were not monitored (Erwin 1991).

Current wetland evaluation methods emphasize vegetation as an indicator of wetland development. One method of assessing vegetation within the Chicago region suggests natural quality (Swink and Wilhelm 1979) and has been used to verify progress toward project goals and the success of establishing native plant communities in restored or created wetlands (Wilhelm and Wetstein 1992a, 1992b). In this method, a numeric value, called the coefficient of conservatism, indicates how limited a native plant is to a particular plant community or set of environmental conditions. A value is assigned to each species and is used to calculate a natural quality index. The index serves as a measure of the floristic integrity of each site; the greater the conservatism of the species and the number of conservative species in a given area, the higher the natural quality (G. Wilhelm, unpublished information).

The development of an ecosystem is a complex process, one that is extremely difficult to reproduce artificially. Consequently, despite the efforts to alleviate wetland loss, evidence has not yet demonstrated that restored or created wetlands adequately function as natural wetlands. Often, designs of wetland restoration or creation projects do not account for the spatial context for the new wetland. Wetlands are dynamic systems, inexorably linked to the adjacent uplands in the watershed. The quality of the uplands will affect the quality and amount of water received by the wetland, in turn influencing the type and quality of the resulting wetland community. Because of this unbreakable link between upland and wetland habitats, the most successful wetland restoration and creation projects involve restoration of adjacent upland buffer zones to native plant communities, such as prairies and forests.

In addition, in restored or created wetlands, relatively few native species are available to colonize and form stable natural communities (G. Wilhelm, unpublished

information). These more conservative species often have particular hydrologic, water quality, and soil pH requirements for germination and growth; they may also require management such as annual burning (G. Wilhelm, unpublished information). Such specific conditions are extremely difficult to duplicate. Consequently, the native floristic diversity of the resulting community often does not match that of a natural wetland (Wilhelm and Wetstein 1992b) (Figure 68). Even when more conservative species are planted to boost the floristic quality, less than half may appear (Wilhelm and Wetstein 1992a) (Figure 69). Species with higher coefficients of conservatism may not grow (Figure 70) (Wilhelm and Wetstein 1992a). At best, 40% of the species planted are usually expected to grow in wetlands that have been designed and managed well—i.e., planted with appropriate species and burned annually (Wilhelm and Wetstein 1992b).

Other failures were caused by an inadequate understanding and implementation of hydrology (the study of the role of water in the system), inappropriate plant species chosen for the site, or unsuitable substrates or soils. Failure with many wetland mitigation projects occurred because a contractor did not follow specifications or the Corps of Engineers did not check on the contractor's compliance and progress (R. Theriout, Corps of Engineers Waterways Experiment Station, personal communication).

More information about these complex wetland systems is needed for restoration and creation. Knowledge about natural systems concerning aspects such as hydrology can be used to improve current design. Additional information gained from the monitoring of restored or created wetlands is essential to predicting the outcome of commonly used restoration and creation methods. Although natural wetlands are self-sustaining systems, more intensive management may be required to maintain the human-influenced restored or created wetlands.

One example of current research in Illinois is the Des Plaines River Wetlands Demonstration Project. This project is a living laboratory designed to provide scientists with research opportunities for evaluating and quantifying how riverine wetlands affect water quality, mitigate flooding, and provide wildlife habitat (Wetlands Research, Inc. 1992). Hydraulically controlled experimental wetlands have been constructed on abandoned farm fields and gravel pits on a 450-acre (182-ha) site in northeastern Illinois in the floodplain of the Des Plaines River. Based on findings from research studies of the natural processes of aquatic systems, the project will develop procedures for design and management that will enable scientists and engineers to reconstruct multifunctional wetlands along rivers.

The Des Plaines River Wetlands Project is a result of the efforts of Wetlands Research, Inc., which was

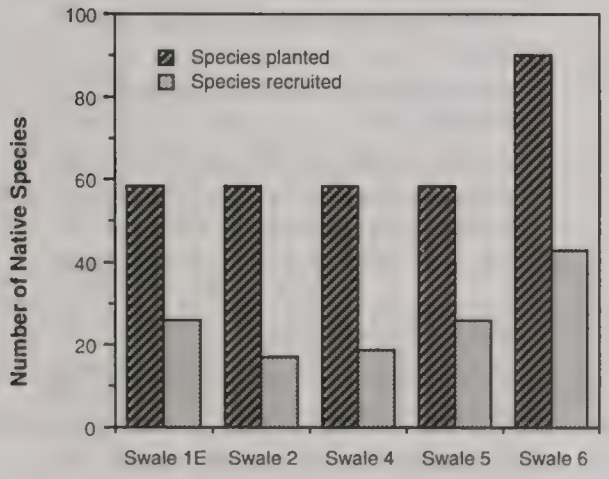

Figure 69. Number of native species planted and number of these species recruited in created wetlands (swales) after four years in Lake County. Source: Wilhelm and Wetstein, 1992a

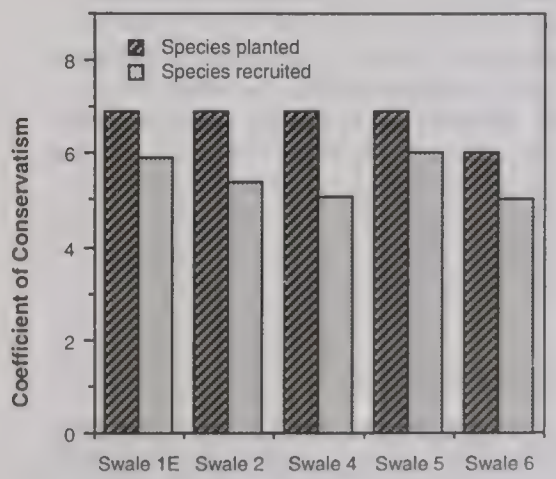

Figure 70. Mean coefficient of conservatism of native species planted and recruited after four years in restored wetlands (swales) in Lake County, 1989 to 1992. Source: Wilhelm and Wetstein, 1992a

formed in 1983 as a joint venture between the Lake County Forest Preserve District and the Openlands Project. Wetlands Research, Inc. is responsible for site management, research coordination, and project administration. The research work is conducted by staff and students of several universities, personnel from state agencies and private consulting organizations, and individual scientists and engineers.

PLANNING EFFORTS

Illinois Wetland Conservation Strategy

The U.S. Environmental Protection Agency initiated a program to assist states, including Illinois, in their wetland efforts by providing funding for a variety of purposes. In Illinois, the major emphasis in the program has been the development of the Illinois Wetland Conservation Strategy (IWCS). This strategy serves as a long-range blueprint to guide a broad spectrum of wetland protection initiatives. The Illinois Department of Conservation executed a contract with Illinois Natural History Survey to assist in the development of the IWCS. In addition, three other planning efforts have been established: the Strategic Planning Process, the Conservation Congress, and the Land Use and Water Resources Priorities Task Force.

The IWCS was divided into two phases to complement the other three planning efforts. Phase 1 of the IWCS, completed 30 April 1993, is designed to incorporate the recommendations from the three planning efforts. Within this initial phase, an assessment of current wetland programs, a discussion of the status of the resource, and a general identification of necessary program changes will be addressed. Phase 2 will provide a detailed assessment of the general recommendations identified in Phase 1. In Phase 2, the pros and cons of each general recommendation will be examined, priorities for action will be identified, and an outline describing the implementation of those priorities will be established.

RESEARCH NEEDS

Wetland research requires a long-term, interdisciplinary commitment because of the complex nature of the wetland environment and the natural variability of the climatic and hydrologic conditions that influence the range of data that can be collected over a short period of time. Several answers are needed regarding many aspects of Illinois wetlands. Wetland subjects for which more information is necessary include:

1. Wetland quality, quantity, and distribution
   - An assessment of the quality of the wetlands remaining in Illinois
   - Periodic updates of the amount and distribution of wetlands in Illinois
   - Effects of sediment, nutrients, and other pollutants on wetlands
   - Methods for managing excessive sediment deposited in wetlands
   - Effects of land-use practices on hydrology and wetlands in watersheds
2. Function and values of wetlands
   - Information regarding the various functions of wetlands
   - Information on the cumulative extent and type of functions of many small wetlands and their effects on the nearby environment
   - Effects on flooding relative to the size and type of wetlands
   - Sediment, nutrient, and pollutant trapping capacity of wetlands
   - Refined economic estimates for the values of wetlands
   - Surface water/groundwater relationships (both quantity and quality) related to wetland values
3. Wetland fauna
   - Long-term population data in Illinois for a variety of wetland mammals, such as muskrats, beaver, and mink
   - Long-term population data on amphibians and reptiles in Illinois
   - Definition of relationships between the numbers of certain waterbird and other animal populations and various types of wetlands in Illinois
4. Mitigation, restoration, and creation of wetlands
   - Methods, monitoring, and economic and biological results for creation of wetlands
   - Methods, monitoring, and economic and biological results for restoration of wetlands

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Appendix 1. Common plant names used in this report with the corresponding scientific names. The suffix spp. (species plural) indicates that two or more species in the genus are included in the discussion.

Common name	Scientific name
Arrowhead	*Sagittaria latifolia*
Bald cypress	*Taxodium distichum*
Black ash	*Fraxinus nigra*
Bluejoint grass	*Calamagrostis canadensis*
Bulrushes	*Scirpus* spp.
Bur-reed	*Sparganium androcladum*
Buttonbush	*Cephalanthus occidentalis*
Cattails	*Typha* spp.
Cordgrass	*Spartina pectinata*
Cottonwood	*Populus deltoides*
Dogwood	*Cornus* spp.
Glossy buckthorn	*Rhamnus frangula*
Grass parnassus	*Parnassia glauca*
Green ash	*Fraxinus pennsylvanica*
Hackberry	*Celtis occidentalis*
Jewel weed	*Impatiens capensis*
Joe-pye-weeds	*Eupatorium* spp.
Manna grass	*Glyceria septentrionalis*
Marsh marigold	*Caltha palustris*
Oaks	*Quercus* spp.
Pickerelweed	*Pontederia cordata*
Purple loosestrife	*Lythrum salicaria*
Red-osier dogwood	*Cornus stolonifera*
Rushes	*Juncus* spp.
Sedges	*Carex* spp.
Silver maple	*Acer saccharinum*
Skunk cabbage	*Symplocarpus foetidus*
Spatterdock	*Nuphar luteum*
Swamp rose	*Rosa palustris*
Sycamore	*Platanus occidentalis*
Tamarack	*Larix laricina*
Thismia	*Thismia americana*
Tussock sedge	*Carex stricta*
Virginia willow	*Itea virginica*
Water lily	*Nymphaea tuberosa*
Water tupelo	*Nyssa aquatica*
Willow	*Salix* spp.

Appendix 2. Approximate amount of hydric soil representing presettlement wetlands in each county of Illinois. The recent survey of hydric soils is currently incomplete. The complete estimate of hydric soil is from Havera (1985).

County name	Number of hydric acres from recent soil survey	Estimated number of hydric acres	Percentage of hydric acres/ county from estimated data
Adams	99,494	164,700	31
Alexander	112,276	47,700	48
Bond	91,187	17,200	7
Boone	127,748	37,400	21
Brown	23,012	35,600	19
Bureau	134,020	104,400	20
Calhoun	36,285	16,600	11
Carroll	--------	19,200	7
Cass	62,550	59,900	26
Champaign	313,275	283,100	47
Christian	159,690	124,300	29
Clark	125,181	62,700	20
Clay	150,336	52,400	19
Clinton	165,965	99,100	32
Coles	117,795	122,300	41
Cook/Dupage	215,171	93,800, 49,700	47, 38
Crawford	104,229	38,900	15
Cumberland	---------	37,500	18
DeKalb	138,500	16,500	4
DeWitt	---------	79,300	33
Douglas	148,792	144,700	56
Edgar	---------	177,500	47
Edwards	202,763	66,900	48
Effingham	118,195	39,800	14
Fayette	162,025	92,300	22
Ford	187,507	140,400	47
Franklin	---------	80,200	31
Fulton	102,500	124,800	24
Gallatin	82,125	87,200	44
Greene	83,200	87,900	26
Grundy	139,240	85,800	35
Hamilton	96,383	96,300	37
Hancock	99,600	62,500	13
Hardin	--------	7,300	8
Henderson	--------	38,600	17
Henry	100,290	77,500	15
Iroquois	402,078	268,400	39
Jackson	---------	105,600	31
Jasper	158,510	71,500	23
Jefferson	---------	42,400	12
Jersey	30,706	48,400	21
Jo Daviess	23,235	26,900	7
Johnson	33,639	32,200	16
Kane	106,976	92,300	31
Kankakee	162,692	106,900	27
Kendall	58,340	57,500	30
Knox	41,345	33,000	8
Lake	67,828	78,000	45
La Salle	213,247	213,700	31

Appendix 2 (continued)

County name	Number of hydric acres from recent soil survey	Estimated number of hydric acres	Percentage of hydric acres/ county from estimated data
Lawrence	86,268	70,800	31
Lee	148,954	111,100	25
Livingston	476,915	276,800	43
Logan	150,660	47,300	12
Macon	157,400	132,700	40
Macoupin	187,734	78,700	15
Madison	180,135	45,900	12
Marion	---	55,400	16
Marshall	---	36,000	15
Mason	116,585	80,800	24
Massac	---	52,700	36
McDonough	82,740	34,100	10
McHenry	103,743	110,800	31
McLean	170,205	190,800	26
Menard	43,272	36,000	19
Mercer	45,815	37,100	11
Monroe	63,255	56,300	24
Montgomery	225,735	93,000	21
Morgan	67,995	29,300	9
Moultrie	---	88,700	42
Ogle	64,260	39,100	8
Peoria	45,165	52,900	15
Perry	---	173,500	65
Piatt	132,465	123,900	46
Pike	45,900	127,200	25
Pope	---	15,200	10
Pulaski	112,276	59,800	53
Putnam	40,370	15,300	15
Randolph	59,168	65,400	19
Richland	257,140	30,800	14
Rock Island	---	33,400	15
St. Clair	---	77,600	21
Saline	74,140	109,800	51
Sangamon	157,265	33,500	7
Schuylar	---	69,800	26
Scott	41,299	36,700	24
Shelby	106,723	37,400	8
Stark	22,300	24,700	14
Stephenson	---	20,400	6
Tazewell	90,460	90,300	24
Union	---	56,500	25
Vermilion	---	245,300	46
Wabash	53,612	48,600	36
Warren	53,745	65,400	20
Washington	---	101,200	29
Wayne	185,930	159,400	37
White	111,660	105,300	35
Whiteside	132,615	65,900	16
Will	184,792	210,300	47
Williamson	---	42,000	19
Winnebago	136,033	42,900	14
Woodford	---	68,100	20
Total	9,412,659	8,261,600	23.1

Appendix 3. Illinois bird species that can use wetlands.

Common name	Scientific name
Common loon	*Gavia immer*
Pied-billed grebe[c]	*Podilymbus podiceps*
Horned grebe	*Podiceps auritus*
Red-necked grebe	*Podiceps grisegena*
Eared grebe	*Podiceps nigricollis*
American white pelican	*Pelecanus erythrorhynchos*
Double-crested cormorant[c]	*Phalacrocorax auritus*
American bittern[b]	*Botaurus lentiginosus*
Least bittern[b]	*Ixobrychus exilis*
Great blue heron	*Ardea herodias*
Great egret[c]	*Casmerodius albus*
Snowy egret[b]	*Egretta thula*
Little blue heron[b]	*Egretta caerulea*
Cattle egret	*Bubulcus ibis*
Green-backed heron	*Butorides striatus*
Black-crowned night-heron[b]	*Nycticorax nycticorax*
Yellow-crowned night-heron[c]	*Nycticorax violaceus*
Tundra swan	*Cygnus columbianus*
Greater white-fronted goose	*Anser albifrons*
Snow goose	*Chen caerulescens*
Canada goose	*Branta canadensis*
Wood duck	*Aix sponsa*
Green-winged teal	*Anas crecca*
American black duck	*Anas rubripes*
Mallard	*Anas platyrhynchos*
Northern pintail	*Anas acuta*
Blue-winged teal	*Anas discors*
Northern shoveler	*Anas clypeata*
Gadwall	*Anas strepera*
American wigeon	*Anas americana*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Greater scaup	*Aythya marila*
Lesser scaup	*Aythya affinis*
Common goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
Hooded merganser	*Lophodytes cucullatus*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*
Ruddy duck	*Oxyura jamaicensis*
Black vulture	*Coragyps atratus*
Turkey vulture	*Cathartes aura*
Osprey[b]	*Pandion haliaetus*
Mississippi kite[b]	*Ictinia mississippiensis*
Bald eagle[a,b]	*Haliaeetus leucocephalus*
Northern harrier[b]	*Circus cyaneus*
Sharp-shinned hawk[b]	*Accipiter striatus*
Cooper's hawk[b]	*Accipiter cooperii*
Northern goshawk	*Accipiter gentilis*
Red-shouldered hawk[b]	*Buteo lineatus*
Broad-winged hawk	*Buteo platypterus*
Swainson's hawk[b]	*Buteo swainsoni*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
American kestrel	*Falco sparverius*
Merlin	*Falco columbarius*
Peregrine falcon[a,b]	*Falco peregrinus*
Ring-necked pheasant	*Phasianus colchicus*
Wild turkey	*Meleagris gallopavo*
Northern bobwhite	*Colinus virginianus*
Yellow rail[b]	*Coturnicops noveboracensis*

Appendix 3 (continued)

Common name	Scientific name
Black rail[b]	*Laterallus jamaicensis*
King rail[c]	*Rallus elegans*
Virginia rail	*Rallus limicola*
Sora	*Porzana carolina*
Purple gallinule	*Porphyrula martinica*
Common moorhen[c]	*Gallinula chloropus*
American coot	*Fulica americana*
Sandhill crane[b]	*Grus canadensis*
Black-bellied plover	*Pluvialis squatarola*
Lesser golden- plover	*Pluvialis dominica*
Semipalmated plover	*Charadrius semipalmatus*
Piping plover[a,b]	*Charadrius melodus*
Killdeer	*Charadrius vociferus*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Solitary sandpiper	*Tringa solitaria*
Willet	*Catoptrophorus semipalmatus*
Spotted sandpiper	*Actitis macularia*
Upland sandpiper[b]	*Bartramia longicauda*
Sanderling	*Calidris alba*
Semipalmated sandpiper	*Calidris pusilla*
Western sandpiper	*Calidris mauri*
Least sandpiper	*Calidris minutilla*
White-rumped sandpiper	*Calidris fuscicollis*
Baird's sandpiper	*Calidris bairdii*
Pectoral sandpiper	*Calidris melanotos*
Dunlin	*Calidris alpina*
Stilt sandpiper	*Calidris himantopus*
Short-billed dowitcher	*Limnodromus griseus*
Long-billed dowitcher	*Limnodromus scolopaceus*
Common snipe	*Gallinago gallinago*
American woodcock	*Scolopax minor*
Wilson's phalarope[b]	*Phalaropus tricolor*
Red-necked phalarope	*Phalaropus lobatus*
Franklin's gull	*Larus pipixcan*
Bonaparte's gull	*Larus philadelphia*
Ring-billed gull	*Larus delawarensis*
Herring gull	*Larus argentatus*
Thayer's gull	*Larus thayeri*
Iceland gull	*Larus glaucoides*
Caspian tern	*Sterna caspia*
Common tern[b]	*Sterna hirundo*
Forster's tern[b]	*Sterna forsteri*
Least tern[a,b]	*Sterna antillarum*
Black tern[b]	*Chlidonias niger*
Rock dove	*Columba livia*
Mourning dove	*Zenaida macroura*
Black-billed cuckoo	*Coccyzus erythropthalmus*
Yellow-billed cuckoo	*Coccyzus americanus*
Common barn-owl[b]	*Tyto alba*
Eastern screech-owl	*Otus asio*
Great horned owl	*Bubo virginianus*
Snowy owl	*Nyctea scandiaca*
Burrowing owl	*Athene cunicularia*
Barred owl	*Strix varia*
Long-eared owl[b]	*Asio otus*
Short-eared owl[b]	*Asio flammeus*
Northern saw-whet owl	*Aegolius acadicus*
Common nighthawk	*Chordeiles minor*
Chuck-will's-widow	*Caprimulgus carolinensis*
Whip-poor-will	*Caprimulgus vociferus*
Chimney swift	*Chaetura pelagica*

Appendix 3 (continued)

Common name	Scientific name
Ruby-throated hummingbird	*Archilochus colubris*
Belted kingfisher	*Ceryle alcyon*
Red-headed woodpecker	*Melanerpes erythrocephalus*
Red-bellied woodpecker	*Melanerpes carolinus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*Picoides villosus*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Olive-sided flycatcher	*Contopus borealis*
Eastern wood-pewee	*Contopus virens*
Yellow-bellied flycatcher	*Empidonax flaviventris*
Acadian flycatcher	*Empidonax virescens*
Alder flycatcher	*Empidonax alnorum*
Willow flycatcher	*Empidonax traillii*
Least flycatcher	*Empidonax minimus*
Eastern phoebe	*Sayornis phoebe*
Great crested flycatcher	*Myiarchus crinitus*
Eastern kingbird	*Tyrannus tyrannus*
Horned lark	*Eremophila alpestris*
Purple martin	*Progne subis*
Tree swallow	*Tachycineta bicolor*
Northern rough-winged swallow	*Stelgidopteryx serripennis*
Bank swallow	*Riparia riparia*
Cliff swallow	*Hirundo pyrrhonota*
Barn swallow	*Hirundo rustica*
Blue jay	*Cyanocitta cristata*
American crow	*Corvus brachyrhynchos*
Fish crow	*Corvus ossifragus*
Common raven	*Corvus corax*
Black-capped chickadee	*Parus atricapillus*
Carolina chickadee	*Parus carolinensis*
Tufted titmouse	*Parus bicolor*
Red-breasted nuthatch	*Sitta canadensis*
White-breasted nuthatch	*Sitta carolinensis*
Brown creeper[c]	*Certhia americana*
Carolina wren	*Thryothorus ludovicianus*
Bewick's wren[b]	*Thryomanes bewickii*
House wren	*Troglodytes aedon*
Winter wren	*Troglodytes troglodytes*
Sedge wren	*Cistothorus platensis*
Marsh wren	*Cistothorus palustris*
Golden-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Blue-gray gnatcatcher	*Polioptila caerulea*
Eastern bluebird	*Sialia sialis*
Veery[c]	*Catharus fuscescens*
Gray-cheeked thrush	*Catharus minimus*
Swainson's thrush	*Catharus ustulatus*
Hermit thrush	*Catharus guttatus*
Wood thrush	*Hylocichla mustelina*
American robin	*Turdus migratorius*
Gray catbird	*Dumetella carolinensis*
Northern mockingbird	*Mimus polyglottos*
Brown thrasher	*Toxostoma rufum*
Cedar waxwing	*Bombycilla cedrorum*
Northern shrike	*Lanius excubitor*
Loggerhead shrike[c]	*Lanius ludovicianus*
European starling	*Sturnus vulgaris*
White-eyed vireo	*Vireo griseus*
Bell's vireo	*Vireo bellii*
Solitary vireo	*Vireo solitarius*

Appendix 3 (continued)

Common name	Scientific name
Yellow-throated vireo	*Vireo flavifrons*
Warbling vireo	*Vireo gilvus*
Philadelphia vireo	*Vireo philadelphicus*
Red-eyed vireo	*Vireo olivaceus*
Blue-winged warbler	*Vermivora pinus*
Golden-winged warbler	*Vermivora chrysoptera*
Tennessee warbler	*Vermivora peregrina*
Orange-crowned warbler	*Vermivora celata*
Nashville warbler	*Vermivora ruficapilla*
Northern parula	*Parula americana*
Yellow warbler	*Dendroica petechia*
Chestnut-sided warbler	*Dendroica pensylvanica*
Magnolia warbler	*Dendroica magnolia*
Cape may warbler	*Dendroica tigrina*
Black-throated blue warbler	*Dendroica caerulescens*
Yellow-rumped warbler	*Dendroica coronata*
Black-throated green warb	*Dendroica virens*
Blackburnian warbler	*Dendroica fusca*
Yellow-throated warbler	*Dendroica dominica*
Pine warbler	*Dendroica pinus*
Prairie warbler	*Dendroica discolor*
Palm warbler	*Dendroica palmarum*
Bay-breasted warbler	*Dendroica castanea*
Blackpoll warbler	*Dendroica striata*
Cerulean warbler	*Dendroica cerulea*
Black-and-white warbler	*Mniotilta varia*
American redstart	*Setophaga ruticilla*
Prothonotary warbler	*Protonotaria citrea*
Worm-eating warbler	*Helmitheros vermivorus*
Swainson's warbler[b]	*Limnothlypis swainsonii*
Ovenbird	*Seiurus aurocapillus*
Northern waterthrush	*Seiurus noveboracensis*
Louisiana waterthrush	*Seiurus motacilla*
Kentucky warbler	*Oporornis formosus*
Connecticut warbler	*Oporornis agilis*
Mourning warbler	*Oporornis philadelphia*
Common yellowthroat	*Geothlypis trichas*
Hooded warbler	*Wilsonia citrina*
Wilson's warbler	*Wilsonia pusilla*
Canada warbler	*Wilsonia canadensis*
Yellow-breasted chat	*Icteria virens*
Summer tanager	*Piranga rubra*
Scarlet tanager	*Piranga olivacea*
Northern cardinal	*Cardinalis cardinalis*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Blue grosbeak	*Guiraca caerulea*
Indigo bunting	*Passerina cyanea*
Green-tailed towhee	*Pipilo chlorurus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
American tree sparrow	*Spizella arborea*
Chipping sparrow	*Spizella passerina*
Clay-colored sparrow	*Spizella pallida*
Field sparrow	*Spizella pusilla*
Vesper sparrow	*Pooecetes gramineus*
Lark sparrow	*Chondestes grammacus*
Savannah sparrow	*Passerculus sandwichensis*
Grasshopper sparrow	*Ammodramus savannarum*
Henslow's sparrow[b]	*Ammodramus henslowii*
Le conte's sparrow	*Ammodramus leconteii*
Sharp-tailed sparrow	*Ammodramus caudacutus*
Fox sparrow	*Passerella iliaca*
Song sparrow	*Melospiza melodia*

Appendix 3 (continued)

Common name	Scientific name
Lincoln's sparrow	*Melospiza lincolnii*
Swamp sparrow	*Melospiza georgiana*
White-throated sparrow	*Zonotrichia albicollis*
White-crowned sparrow	*Zonotrichia leucophrys*
Dark-eyed junco	*Junco hyemalis*
Lapland longspur	*Calcarius lapponicus*
Smith's longspur	*Calcarius pictus*
Snow bunting	*Plectrophenax nivalis*
Bobolink	*Dolichonyx oryzivorus*
Red-winged blackbird	*Agelaius phoeniceus*
Eastern meadowlark	*Sturnella magna*
Western meadowlark	*Sturnella neglecta*
Yellow-headed blackbird[b]	*Xanthocephalus xanthocephalus*
Rusty blackbird	*Euphagus carolinus*
Brewer's blackbird	*Euphagus cyanocephalus*
Common grackle	*Quiscalus quiscula*
Brown-headed cowbird	*Molothrus ater*
Orchard oriole	*Icterus spurius*
Northern oriole	*Icterus galbula*
Purple finch	*Carpodacus purpureus*
House finch	*Carpodacus mexicanus*
Red crossbill	*Loxia curvirostra*
White-winged crossbill	*Loxia leucoptera*
Common redpoll	*Carduelis flammea*
Pine siskin	*Carduelis pinus*
American goldfinch	*Carduelis tristis*
Evening grosbeak	*Coccothraustes vespertinus*
House sparrow	*Passer domesticus*
Eurasian tree sparrow	*Passer montanus*

[a] Federally endangered.
[b] State endangered.
[c] State threatened.

Appendix 4. Mammal species in Illinois that use wetlands.

Common name	Scientific name
Virginia opossum	*Didelphis virginiana*
Masked shrew	*Sorex cinereus*
Southeastern shrew	*Sorex longirostris*
Northern short-tailed shrew	*Blarina brevicauda*
Southern short-tailed shrew	*Blarina carolinensis*
Eastern mole	*Scalopus aquaticus*
Little brown bat	*Myotis lucifugus*
Indiana bat[a]	*Myotis sodalis*
Southeastern bat[b]	*Myotis austroriparius*
Gray bat[a]	*Myotis grisescens*
Northern long-eared bat	*Myotis septentrionalis*
Silver-haired bat	*Lasionycteris noctivagans*
Eastern pipistrelle	*Pipistrellus subflavus*
Big brown bat	*Eptesicus fuscus*
Red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Evening bat	*Nycticeius humeralis*
Rafinesque's big-eared bat[b]	*Plecotus rafinesquii*
Swamp rabbit	*Sylvilagus aquaticus*
Franklin's ground squirrel	*Spermophilus franklinii*
Gray squirrel	*Sciurus carolinensis*
Fox squirrel	*Sciurus niger*
Southern flying squirrel	*Glaucomys volans*
Beaver	*Castor canadensis*
Marsh rice rat[c]	*Oryzomys palustris*
Western harvest mouse	*Reithrodontomys megalotis*
White-footed mouse	*Peromyscus leucopus*
Golden mouse[c]	*Ochrotomys nuttalli*
Meadow vole	*Microtus pennsylvanicus*
Prairie vole	*Microtus ochrogaster*
Woodland vole	*Microtus pinetorum*
Muskrat	*Ondatra zibethicus*
Southern bog lemming	*Synaptomys cooperi*
House mouse	*Mus musculus*
Meadow jumping mouse	*Zapus hudsonius*
Coyote	*Canis latrans*
Red fox	*Vulpes vulpes*
Gray fox	*Urocyon cinereoargenteus*
Raccoon	*Procyon lotor*
Least weasel	*Mustela nivalis*
Long-tailed weasel	*Mustela frenata*
Mink	*Mustela vison*
Striped skunk	*Mephitis mephitis*
River otter[b]	*Lutra canadensis*
Bobcat[c]	*Lynx rufus*
White-tailed deer	*Odocoileus virginianus*

[a] Federally endangered.
[b] State endangered.
[c] State threatened.

Appendix 5. Amphibian species in Illinois that use wetlands.

Common name	Scientific name
Jefferson salamander	*Ambystoma jeffersonianum*
Blue-spotted salamander	*Ambystoma laterale*
Spotted salamander	*Ambystoma maculatum*
Marbled salamander	*Ambystoma opacum*
Silvery salamander[a]	*Ambystoma platineum*
Mole salamander	*Ambystoma talpoideum*
Smallmouth salamander	*Ambystoma texanum*
Tiger salamander	*Ambystoma tigrinum*
Eastern newt	*Notophthalamus viridescens*
Dusky salamander[a]	*Desmognathus fuscus*
Southern two-lined salamander	*Eurycea cirrigera*
Longtail salamander	*Eurycea longicauda*
Cave salamander	*Eurycea lucifuga*
Four-toed salamander	*Hemidactylium scutatum*
Mudpuppy	*Necturus maculosus*
Lesser siren	*Siren intermedia*
Eastern spadefoot toad	*Scaphiopus holbrookii*
American toad	*Bufo americanus*
Fowler's toad	*Bufo woodhousii*
Northern cricket frog	*Acris crepitans*
Bird-voiced treefrog	*Hyla avivoca*
Cope's gray treefrog	*Hyla chrysoscelis*
Green treefrog	*Hyla cinerea*
Gray treefrog	*Hyla versicolor*
Spring peeper	*Pseudacris crucifer*
Upland chorus frog	*Pseudacris feriarum*
Illinois chorus frog[b]	*Pseudacris streckeri*
Western chorus frog	*Pseudacris triseriata*
Crawfish frog	*Rana areolata*
Plains leopard frog	*Rana blairi*
Bullfrog	*Rana catesbeiana*
Green frog	*Rana clamitans*
Pickerel frog	*Rana palustris*
Northern leopard frog	*Rana pipiens*
Wood frog	*Rana sylvatica*
Southern leopard frog	*Rana utricularia*
Eastern narrowmouth toad	*Gastrophryne carolinensis*

[a] State endangered.
[b] State threatened.

Appendix 6. Reptile species in Illinois that use wetlands.

Common name	Scientific name
Snapping turtle	*Chelydra serpentina*
Alligator snapping turtle	*Macroclemys temminckii*
Illinois mud turtle[a]	*Kinosternon flavescens*
Eastern mud turtle	*Kinosternon subrubrum*
Common musk turtle	*Sternotherus odoratus*
Painted turtle	*Chrysemys picta*
Common slider	*Trachemys scripta*
River cooter[a]	*Pseudemys concinna*
Spotted turtle[a]	*Clemmys guttata*
Blanding's turtle	*Emydoidea blandingii*
Common map turtle	*Graptemys geographica*
False map turtle	*Graptemys pseudogeographica*
Eastern box turtle	*Terrepene carolina*
Smooth softshell turtle	*Apalone mutica*
Spiny softshell turtle	*Apalone spinifera*
Eastern fence lizard	*Sceloporus undulatus*
Five-lined skink	*Eumeces fasciatus*
Broadhead skink	*Eumeces laticeps*
Ground skink	*Scincella lateralis*
Worm snake	*Carphophis amoenus*
Kirtland's snake	*Clonophis kirtlandii*
Racer	*Coluber constrictor*
Ringneck snake	*Diadophis punctatus*
Great plains rat snake[b]	*Elaphe guttata*
Rat snake	*Elaphe obsoleta*
Mud snake	*Farancia abacura*
Eastern hognose snake	*Heterodon platyrhinos*
Common kingsnake	*Lampropeltis getula*
Green water snake[b]	*Nerodia cyclopion*
Plainbelly water snake	*Nerodia erythrogaster*
Broad-banded water snake[a]	*Nerodia fasciata*
Diamondback water snake	*Nerodia rhombifer*
Northern water snake	*Nerodia sipedon*
Rough green snake	*Opheodrys aestivus*
Smooth green snake	*Opheodrys vernalis*
Graham's crayfish snake	*Regina grahamii*
Brown snake	*Storeria dekayi*
Redbelly snake	*Storeria occipitomaculata*
Western ribbon snake	*Thamnophis proximus*
Plains garter snake	*Thamnophis radix*
Eastern ribbon snake[a]	*Thamnophis sauritus*
Common garter snake	*Thamnophis sirtalis*
Smooth earth snake	*Virginia valeriae*
Copperhead	*Agkistrodon contortrix*
Cottonmouth	*Agkistrodon piscivorus*
Timber rattlesnake	*Crotalus horridus*
Massasauga	*Sistrurus catenatus*

[a] State endangered.
[b] State threatened.

Appendix 7. Threatened and endangered fish that use wetlands.

Common name	Scientific name
Least brook lamprey	*Lampetra aegyptera*
Alligator gar	*Atractosteus spatula*
Cypress minnow	*Hybognathus hayi*
Pugnose shiner	*Notropis anogenus*
Ironcolor shiner	*Notropis chalybaeus*
Blackchin shiner	*Notropis heterodon*
Blacknose shiner	*Notropis heterolepis*
Bluehead shiner	*Pteronotropis hubbsi*
Banded killifish	*Fundulus diaphanus*
Spotted sunfish	*Lepomis punctatus*
Bantam sunfish	*Lepomis symmetricus*
Iowa darter	*Etheostoma exile*

LAKES AND IMPOUNDMENTS

SUMMARY

Lakes and impoundments have reflected the effects of intensive agriculture, urbanization, industrialization, and species introductions, all of which have accelerated since World War II. Significant changes in fish species compositions have occurred in Lake Michigan due to deliberate and accidental species introductions (exotics now constitute 17% of all fish species), shoreline habitat and drainage area deterioration, and over-exploitation of some fish stocks. Recreational fishing in the Illinois part of Lake Michigan is now dominated by a native yellow perch fishery and a subsidized, introduced salmonid fishery.

Because impoundment construction accelerated after many land-use changes had begun, data indicating trends in impoundments are limited. However, soil loss due to row-crop and livestock farming, in addition to the removal of stream riparian vegetation, has resulted in high sedimentation rates that are capable of filling some impoundments in less than 100 years. Most impoundments are also artificially eutrophicated due to agricultural fertilizers and urban waste. There is no evidence for multispecies overexploitation in impoundments by recreational or commercial fishermen, when overexploitation is defined as a decrease in total yield when fishing effort increases. The definition of overexploitation of individual fish species stocks depends on the size structure of fish desired, but there is no evidence of recruitment failures or extinctions due to excessive exploitation. Major increases in expenditure on the stocking of fish have occurred, but the benefits of stocking to specific angling groups compared to the overall benefits of improving habitat and other management alternatives have not been explored.

INTRODUCTION

True lakes are restricted to the extreme northeast of Illinois because of the effects of glaciation. Lake Michigan is the conspicuous example of this set because of its size and historical importance and is treated in a separate section. The only other natural lakes are the few remaining floodplain lakes that are more appropriately considered as part of a river-floodplain system. Human-made lakes—which range from the three U.S. Army Corps of Engineers reservoirs (Rend Lake, Lake Shelbyville, and Lake Carlyle) down to small farm ponds—have come to dominate the existing lacustrine environment due largely to an acceleration in construction in the 1960s (Figure 1).

Data useful for environmental trend analysis from impoundments and small lakes were found to be sparse. This, in combination with the limited time since construction, results in only a few time-series from impoundments of sufficient quality to assist in critical trend assessments. However, the effects of changes in

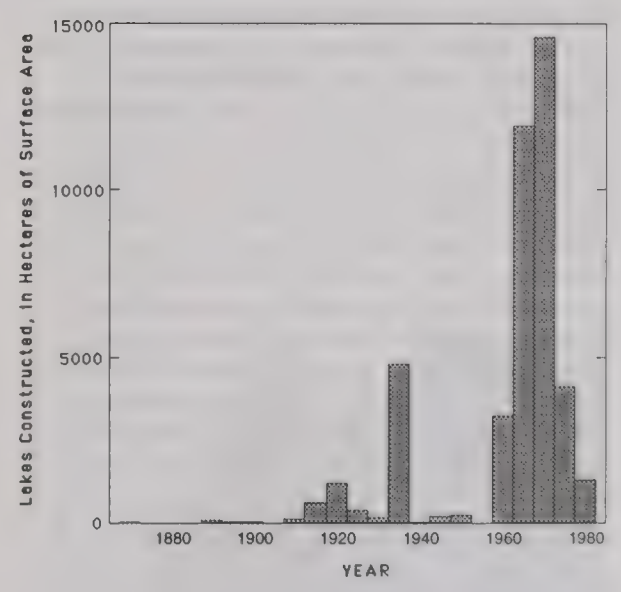


Figure 1. Amount of lake surface area created by impounding streams and rivers during 5-year time periods since 1880. Data reflect the construction of a set of 124 lakes throughout Illinois. No significant surface area has been added since 1980. The peak in 1935 reflects the construction of Lake Springfield and the increase in water level on the Fox Chain O' Lakes, which are natural lakes that were affected by the construction of McHenry Dam on the Fox River. The peak during 1960–1975 represents the major period of lake construction, which included the three U.S. Army Corps of Engineers reservoirs (Carlyle, Rend, and Shelbyville).

land use, such as the greatly increased use of agricultural fertilizers in the past 30 years, has been patently obvious on the majority of lakes in agricultural watersheds. Such lakes exhibit all the signs of eutrophication, such as excessive algal and macrophyte growth and anoxic water below the thermocline in the summer.

Lakes and impoundments are the repository of much waste (e.g., soil, toxic chemicals, nutrients) carried in by rivers and therefore have the potential to act as environmental barometers. In addition, they are resources in that they attract significant recreational and commercial fishing, long-term records of which might demonstrate their sustainability and reflect environmental change in the future.

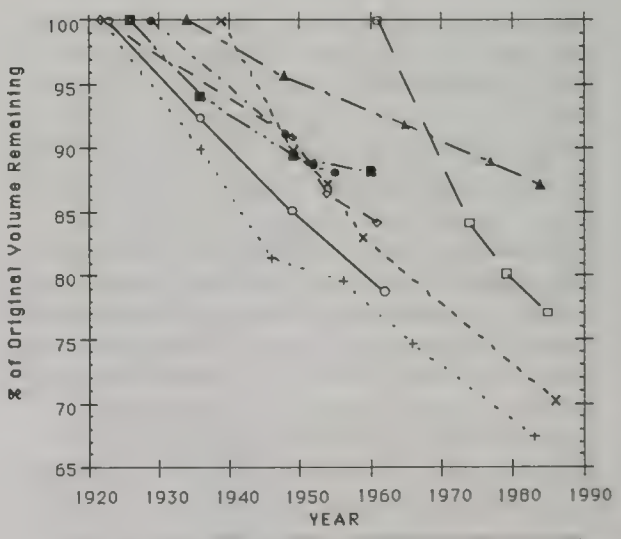
IMPOUNDMENTS/SMALL LAKES

Abiotic Factors

Sedimentation. The rate of sedimentation is probably the strongest indicator of external environmental change affecting impoundments. Although sediment transport by rivers is natural and the lifetime of all lakes is finite, the rate of accumulation of sediments in the majority of our lakes has been phenomenal (Figure 2). This is mainly due to row-crop and livestock-based agriculture practices, which have accelerated since the 1950s, and the concurrent decrease in natural riparian vegetation bordering affluent streams. The issue is not just the effect of rapid additions of new sediment, which can negatively affect macrophyte growth, benthos production, and spawning/nursery areas for some fish, but the lifetime of the lake. For example, Lake Decatur has lost a third of its volume in 60 years, and Lake Pittsfield has lost nearly a quarter of its volume in only 24 years (Figure 2). Correcting this process by dredging is very expensive, a cost which, in turn, can be minor compared with the disposal of pesticide-contaminated spoil. The only viable long-term solution is to change land-use practices, particularly with regard to row-crop agriculture, livestock farming, and stream corridors.

Water Quality. Data series on impoundments are currently too limited to observe trends that are expected from agricultural and urban inputs, whose major effects are clear from the longer time series available from rivers. Most impoundments were constructed after the acceleration of intensified row-crop and livestock-based agriculture and associated fertilizer and pesticide additions occurred.

Hydrology. Hydrology is often an ignored factor in lakes because it is assumed that their water level fluctuations are limited and unimportant. In fact, a predictable spring rise and steady retreat in summer can be extremely important for the spawning and/or nursery grounds for many fish species, just as it is in rivers. Water levels during 15 years are compared in Figure 3 for three U.S. Army Corps of Engineers reservoirs: Rend Lake, Lake Carlyle, and Lake Shelbyville. Rend Lake has a fixed spillway, so water level is a function of rainfall, runoff, and the capacity of the system, and produces a fairly predictable flood pulse in the spring and few surprises at other times of the year (Figure 3). Conversely, Lakes Carlyle and Shelbyville are manipulated in an attempt to prevent the natural flooding process downstream. This results in drawdowns when large inflows are expected, resulting in spawning and nursery areas for some species being dry during critical periods in the spring.



Symbol	Lake Name	County	Original Capacity (acre-feet)
—○—	Lake Bracken	Knox	2881
—□—	Lake Pittsfield	Pike	3580
—◇—	Arctic Lake	Macoupin	176
- -×- -	Lake Carlinville	Macoupin	2350
· ·+· ·	Lake Decatur	Macon	27900
—△—	Lake Springfield	Sangamon	59900
- -●- -	Lake Bloomington	McLean	6650
—■—	Frankfurt Res.	Franklin	1700

Figure 2. Storage capacity loss for eight Illinois lakes. Lakes with four or more sedimentation studies were selected for this analysis from data in Singh and Durgunoglu (1990). These eight lakes currently have an average storage capacity loss of 0.52%/year. This loss is primarily attributable to siltation as a result of soil erosion. Future land use practices will determine to a large extent whether this pattern will continue.

Most impoundments are unregulated but do not necessarily have good spawning and rearing habitats. This is a subject for research when current fishery data programs produce sufficiently long time-series.

Recreational Fishing

Sport fishing license sales generally increased from 1941 through 1971, followed by a stable period in which a slight decline was noted (Figure 4). However, these data do not account for angling by senior citizens (except for 1960–1975) and minors, who do not need licenses.

Since 1977, recreational fishing effort in the U.S. Army Corps of Engineers reservoirs (and in Lake Michigan) has tended to decline, while in the remaining bodies of water it has, at least until 1986, steadily increased (Figure 5) without a parallel increase in fishable waters. However, total harvest has been strongly positively related to fishing effort in all impoundments sampled in recent years (Figure 6), and higher harvest rates were not obtained at the cost of inferior fish species or smaller fish. Overexploitation of the total fish resource, which would have been indicated with a flat or negative relationship between harvest and effort, is evidently not a concern. However, the ability of lakes to produce more fish may be constrained by environmental factors.

Time series of recreational harvest and effort data on individual lakes are too limited to draw definite conclusions, but scattered data from reservoirs (Figure 7) do not suggest any trends during 25 years in a general index of sport fish biomass. However, even though total weight of catch may have been maintained, angler satisfaction may have been negatively affected by reduced mean size of fish caught in some impoundments.

Commercial Fishing

Nonriverine commercial fishing has been confined to a few lakes, among which two U.S. Army Corps of Engineers reservoirs, Carlyle and Rend Lakes (Figure 8), attract the most effort. These fisheries are heavily controlled to minimize conflicts with recreational fisheries; therefore, harvest is mainly limited by how much time the fishermen can operate each year. When fishing effort is accounted for, the overall trend does not suggest that the resource, consisting mostly of common carp and various buffalo species, is being depleted by the fishery (Arnold W. Fritz, Illinois Department of Conservation, personal communication). It should be added that these species are generally more tolerant of poor water quality and high rates of sedimentation and are not sought by most recreational fishermen.

Fish Stocking

A variety of species have been stocked in lakes (see also Lake Michigan below), and quantities stocked

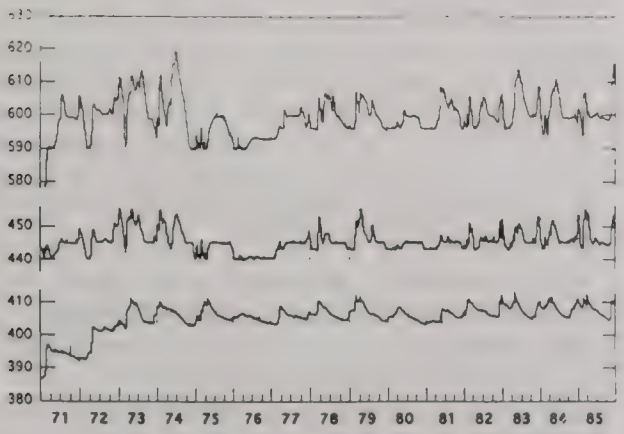


Figure 3. Daily water levels (feet above sea level) for 1971–1985 for three U.S. Army Corps of Engineers reservoirs. Levels of Lake Shelbyville (top) and Carlyle Lake (middle) are regulated, whereas Rend Lake (bottom) has an unregulated spillway. Data are from the U.S. Army Corps of Engineers, St. Louis.

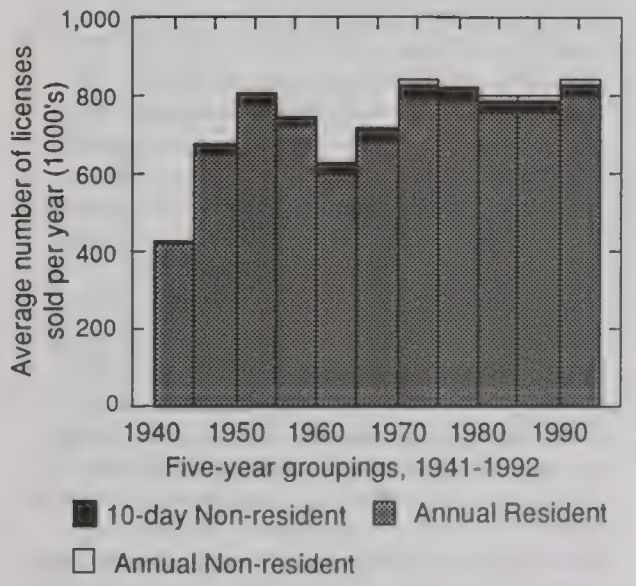


Figure 4. Resident and nonresident Illinois sport fishing license sales for various five-year periods (data from Illinois Department of Conservation). Before 1950 licenses were not required for anglers less than 18 years old, and beginning in 1950 those less than 16 years old were exempt. Senior licenses sold during 1960–1975 are excluded from this data set.

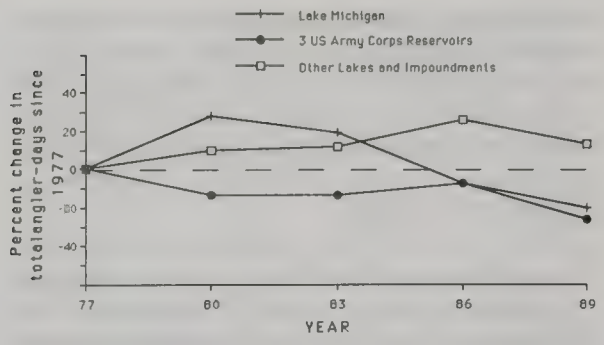


Figure 5. Changes in the number of angler-days spent on recreational fishing at various Illinois lakes according to a mail survey conducted every three years by the Illinois Department of Conservation. Values are expressed as the percent change relative to the number of angler-hours spent at each group of lakes in 1977. Absolute values are not given because these are inflated by nonresponse and recall biases (Tarrant et al. 1993); the relative changes shown here assume that these biases were consistent among years. "Other lakes and impoundments," which include state conservation lakes, public lakes, organizational lakes, daily fee lakes, and private lakes, are subject to the majority of the total angling effort.

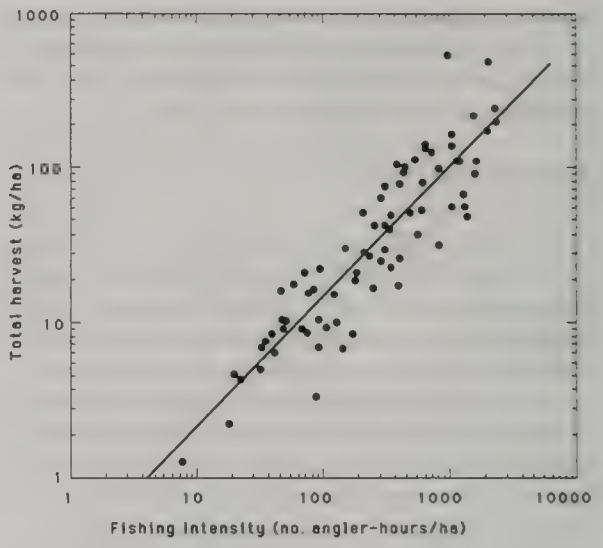


Figure 6. Relationship between harvest (kg/ha) and fishing intensity (angler-hours/ha) for all species of fish harvested from 76 annual creels (spring-autumn) from 43 Illinois lakes. The regression line explained 81% of the variance in harvest. Data are from 66 recreational fishery surveys conducted by Illinois Natural History Survey staff between 1987 and 1992 (Bayley et al. 1990, 1991, 1993) and from other surveys by Southern Illinois University and the Illinois Department of Conservation.

have increased since the 1970s (Figure 9). Part of this is a response to increased fishing pressure, part is due to the stocking of new or reconstituted lakes, and part is due to a desire for particular coolwater species such as walleye and muskellunge that have limited reproduction because of inappropriate environmental conditions. None of these species programs has been been adequately supported by additional license charges—even for salmonids, for which an additional fee is charged—although modest modest fee increases were instituted in 1979 and 1982 for hatchery investment and stocking. Expenditures on fish production for stocking (including hatcheries) have constituted 33% of the total operating budget of the Division of Fisheries of the Illinois Department of Conservation (Illinois State Budget Detail, Fiscal Year 1992) for the past seven years. Therefore, evaluations of the cost-effectiveness of various rearing and stocking strategies need to be related to angler demand for these fish species. These estimates need to be compared with the cost-effectiveness of alternative management approaches such as habitat restoration and promotion of catch-and-release which benefit most anglers. In recent years, steps have been taken to make these evaluations and improvements, so that a more objective appraisal of the costs and benefits of fish stocking will be possible.

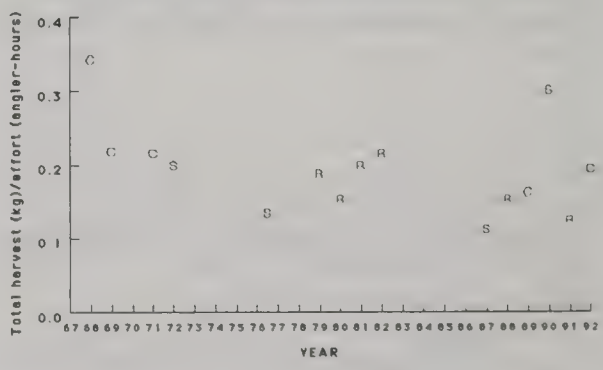


Figure 7. Recreational harvest (kg) per unit effort (angler-hours) as a measure of sport fish biomass for Lake Shelbyville (S), Carlyle Lake (C), and Rend Lake (R). Data are from recreational fishery surveys conducted by the Illinois Natural History Survey (Bayley et al. 1990, 1991, 1993), Southern Illinois University, and the Illinois Department of Conservation.

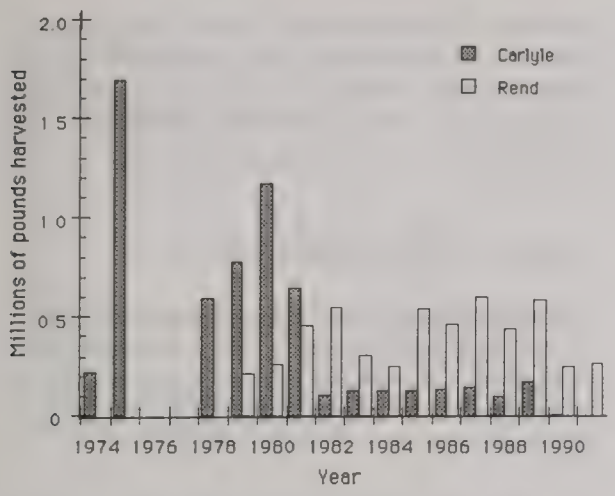


Figure 8. Commercial fishing harvest from Lake Carlyle and Rend Lake during 1974–1991. Data are from the Illinois Department of Conservation. Primary species included in the harvest are buffalo (Ictiobus spp.), carp (Cyprinus carpio), and freshwater drum (Aplodinotus grunniens). Of the total 1989 Illinois commercial fish harvest, 2.7% came from Lake Carlyle, 8.9% from Rend Lake, and 67.5% from the Mississippi River.

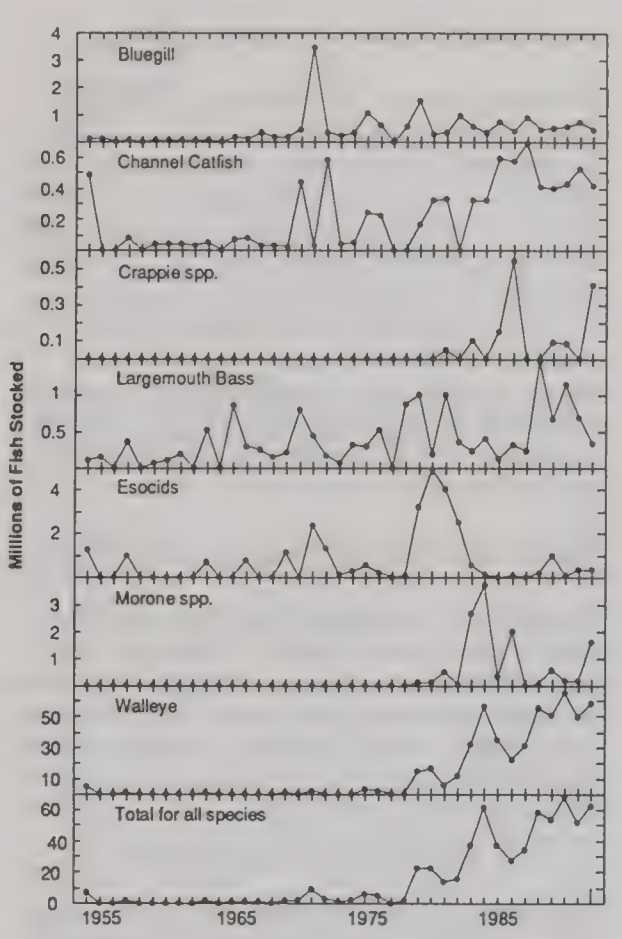


Figure 9. Numbers of fish stocked into all Illinois lakes and reservoirs, 1954 to 1992. Crappie spp. include white crappie, black crappie, and hybrids; esocids include northern pike, muskellunge, and hybrids; Morone spp. include striped bass, white bass, and hybrids. The bottom graph depicts the totals for all species, including some not shown in other graphs.

LAKE MICHIGAN

Lake Michigan is the third largest of the Great Lakes and the sixth largest freshwater lake in the world. The lake is 307 miles from north to south, with a maximum width of 118 miles. The average depth is 85 m (279 ft), and the deepest basin is at 282 m (925 ft). The main basin of the lake is oligotrophic. In contrast, Green Bay on the northwestern edge of Lake Michigan has a maximum depth of 35 m (110 ft). This warm, eutrophic system is inhabited by a fauna that is not found elsewhere in the lake and will not be addressed in this document. The main drainage of the lake is through the Mackinac Straits at the north end into Lake Huron, and the retention time of water in Lake Michigan is estimated at 99 years. The Lake Michigan basin is composed of glacial till varying from hard pan clay to bedrock, gravel, and cobble; several reef areas—notably the Sheboygan Reef complex, Julian's Reef, Wilmette Reef and Highland Park Reef—are composed of solid and broken bedrock.

Lake Michigan's water and resources are shared and managed by four states: Michigan, Wisconsin, Illinois, and Indiana. The sport fishery is the second largest in the Great Lakes, with an estimated economic impact of $332 million annually. Commercial fishing brings in 50 million pounds of fish annually with a 1986 value of $16.4 million. As of 1970 the shoreline usage was 39% urban and industry, 20% agriculture, 12% recreation, and 29% forested or other use.

The drainage basin of the Great Lakes is at its narrowest in Illinois, at a minimum of less than 4 miles wide near Waukegan. The Illinois portion of Lake Michigan is relatively shallow and is characterized by a smooth shoreline with few rivers, no natural bays or islands, and many small nearshore and offshore reefs.

Importance of Lake Michigan to Illinois

The Illinois shoreline of Lake Michigan is only 66 miles long (4% of the total lake shoreline), but the communities along the shoreline, dominated by Chicago, are inhabited by approximately 8.3 million people. This population constitutes a disproportionate percentage (36%) of the total population in the drainage basin and represents 70% of the population of Illinois (11.7 million). Communities along the lakeshore depend upon the lake for potable water, cooling water for power generating stations, industrial processing, transport of goods into and out of the area, commercial fishing, sport fishing, recreational boating, beaches, and tourist attractions.

History of the Illinois Waters of Lake Michigan

The history of the Lake Michigan watershed is one of exploitation. Because the lake is a contiguous ecosystem, the history of the Illinois waters of the lake cannot always be disassociated from the history of the whole lake. However, many of the human impacts on the lake are focused at the point of highest population density: Chicago. Chicago underwent an almost exponential population growth in the 1800s, expanding from approximately 50 settlers in 1830 to over 1.7 million inhabitants by 1900. Lake Michigan and the Chicago River provided settlers with several vital resources — water for consumption, power, industry, navigation, and fishing. As the Chicago area was settled, logging, farming, industry, and human habitation introduced organic pollution and silt into the lake. The waters near Chicago became so fouled in the late 1800s that diseases associated with polluted waters became a major public problem. The "solution" was the construction of the Chicago Sanitary and Ship Canal, completed in 1900, which reversed the flow of the Chicago River and sent Chicago's wastes into the Des Plaines River instead of the lake. As Chicago grew, the need for land led to the filling of shallow lakeshore areas and the consequent destruction of wetlands and spawning areas. Siltation also contributed to degradation of nearshore benthic habitats, including the whitefish and possibly lake trout spawning grounds.

Major commercial fisheries for chubs, lake trout, and whitefish were established in Illinois in the early 1800s, and by the mid-1800s had begun to contribute to severe declines in the fish stocks. Boat navigation among the Great Lakes and between the Great Lakes and Europe was enhanced in the late 1800s and mid-1900s by the construction of the Welland Canal and the St. Lawrence Seaway. These changes permitted the introduction of nonindigenous ("exotic") species into the Great Lakes via ballast water, solid ballast, and fish migration. Many of the introduced species, particularly the sea lamprey, alewife, and smelt, contributed to declines in native species through competition and predation.

Critical Trends in Lake Michigan

Declines of Native Fish Stocks. Several native fish species in Lake Michigan have declined due directly or indirectly to anthropogenic effects (Figures 10–16). Several species that are important to sport and commercial fisheries have declined in this century.

The native forage fish community in the lake was dominated by coregonines (ciscoes, whitefish, lake herring, and bloater), sculpins, and yellow perch (see Figure 10). The major predators were lake trout and burbot. In the past century, most of these species (14% of the total fish species) were either extirpated or underwent severe declines. Recovery of many species has been slow, in large part due to the effects of exotic species, habitat degradation, and a reduction in water quality. The role of the major predators and major forage species has been replaced by exotic species, leading to unstable fish stocks with fluctuating population densities.

The yellow perch is currently an important commercial species in the Illinois waters of Lake Michigan, as well as throughout the Great Lakes (Figure 11). Commercial fishermen can sell whole fish for up to $2 per pound,

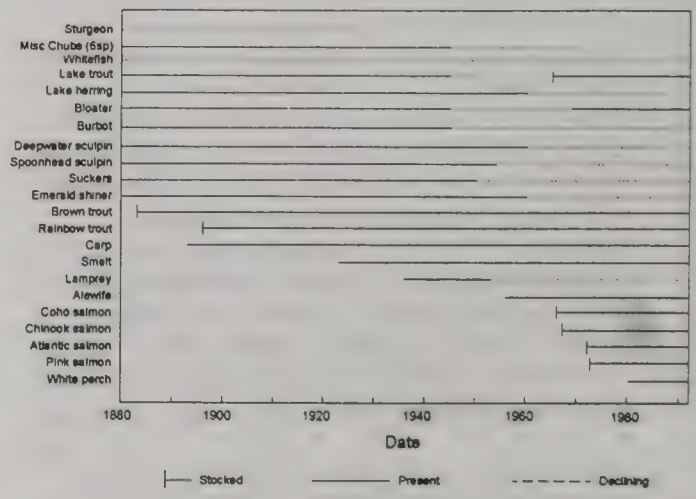


Figure 10. Changes in the species composition of Lake Michigan.

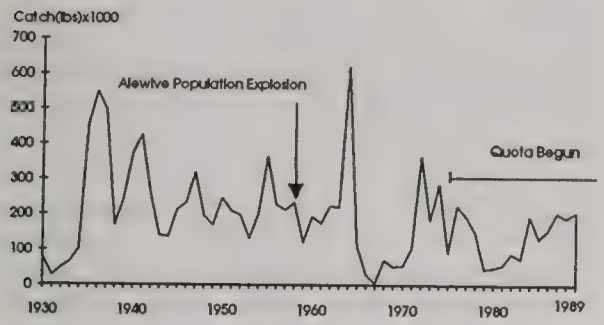


Figure 11. Illinois yellow perch commercial harvest from Lake Michigan, 1930–1989.

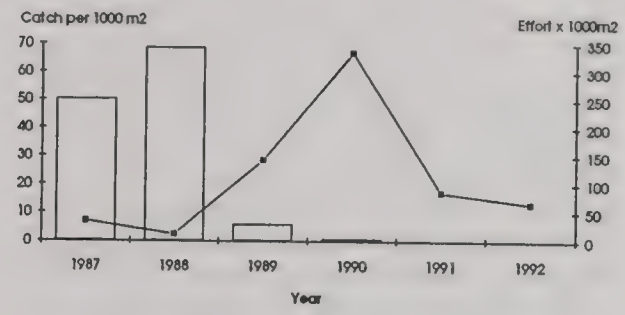


Figure 12. Catch of young yellow perch in Illinois waters of Lake Michigan, 1987–1992.

while retailers often sell the fillets for $8 to $11 per pound. Because yellow perch inhabit shallow, near-shore waters in spring and summer, they constitute the largest component of the Illinois recreational fishery. An average of 1.5 million fish were caught annually between 1986 and 1991, with over 90% being caught by shore anglers (Horns and Brofka 1992).

Yellow perch were not always as highly valued or abundant as they are today. Before the 1960s, they were a low-value species compared to lake trout or deepwater ciscos. Prices paid to fishermen often varied between 5 and 10 cents per pound—if the fishermen could find a buyer (H. Strege, personal communication). During the 1960s, the yellow perch population declined from competition with and predation by alewives.

Beginning in 1980, the yellow perch population exploded in response to the decline in alewife abundance. During the 1980s, three strong year classes of yellow perch (1980, 1983, and 1987) were observed by Illinois Natural History Survey staff at Zion and by other state and federal agency personnel. These strong year classes were interspersed with moderate to weak year classes.

Illinois Natural History Survey bottom trawl surveys conducted in the fall of each year for young yellow perch indicated very weak to nonexistent year classes for 1989–1992 (Figure 12). This was corroborated by other government agencies (Wisconsin Department of Natural Resources, Michigan Department of Natural Resources, U.S. Fish and Wildlife Service) that conduct surveys of yellow perch young-of-the-year abundance. Because yellow perch in southwestern Lake Michigan are relatively slow growing and long lived, the effects of the absence of these year classes

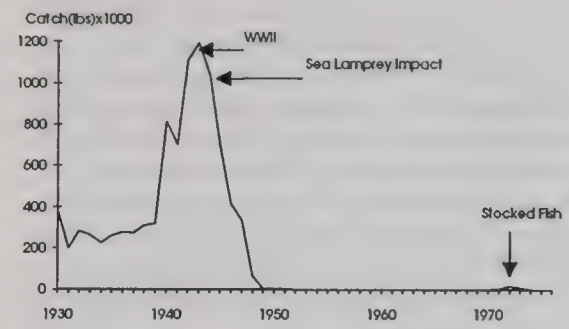


Figure 13. Illinois commercial lake trout harvest from Lake Michigan, 1930–1992.

have yet to be felt. The recent influx of exotic invaders (zebra mussel, spiny water flea, rusty crayfish, and white perch) may have an impact on the yellow perch population in the next decade.

Before 1946, lake trout was the most important commercial species in the Great Lakes (Figure 13). From 1926 to 1939, lake trout commercial harvests in the Illinois portion of Lake Michigan were fairly stable, with 150,000 to 300,000 lb harvested annually. During 1942 to 1944 (World War II), lake trout harvest increased dramatically to over 1,000,000 lb per year. The lake trout harvest then began a steep plunge from 694,000 lb in 1943 to 2,000 lb in 1951 (Baldwin et al. 1979). A combination of sea lamprey predation and overfishing completely eliminated the Lake Michigan populations by 1956 (Wells and McLain 1973).

The goal of state, provincial, and federal agencies is to restore self-sustaining populations of lake trout throughout the Great Lakes. To this end, lamprey control was implemented in Lake Michigan in the early

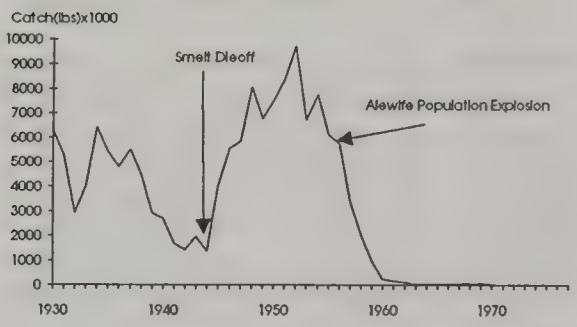


Figure 14 . Commercial harvest of lake herring from Lake Michigan, 1930–1992.

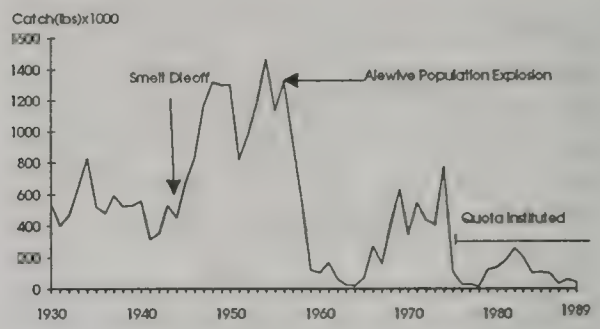


Figure 15. Illinois commercial harvest of deepwater ciscos in lake Michigan, 1930–1989.

1960s, and lake trout stocking began in 1965. Stocked lake trout are now abundant throughout Lake Michigan, but there has been little evidence of natural reproduction. Lack of successful recruitment may be due to the stocking of inappropriate genetic strains, the effects of maternal loading of contaminants on the eggs, an absence of suitable spawning substrate, and the effects of overexploitation of adult stocks. Until the factors affecting natural recruitment are understood and eliminated, the maintenance of adult populations in Lake Michigan depends on stocking.

Lake trout have become an important component of the recreational fishery throughout Lake Michigan, especially for the charter boat industry. In the Illinois charter fishery, lake trout made up 21% of the salmonid catch between 1986 and 1989 (Hess 1991). Lake trout are usually easy to find and catch in the summer, replacing chinook salmon as the bread and butter fish of the summer charter fishery. Because of tissue contamination from various organic chemical compounds, Lake Michigan lake trout cannot be sold commercially. Also, commercial fishing for lake trout is incompatible with the goal of lake trout population rehabilitation.

The lake herring is not a true herring but a shallow-water cisco. Historically, lake herring was an important commercial species, often being the most commonly caught species in the late 19th and early 20th century (Figure 14). Most of the Lake Michigan production occurred in the waters of Green Bay. However, lake herring was a component of the Illinois commercial fishery from 1926 to 1952, with annual catches ranging from 14,000 lb to 201,000 lb (Baldwin et al. 1979). Because lake herring is a relatively low market value fish, the periods of low harvest were due more to lack of demand than to low abundance. However, with the

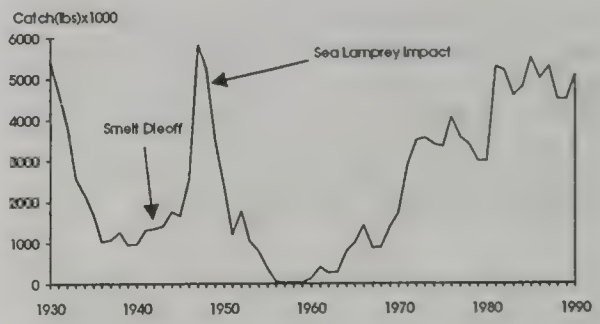


Figure 16 . Commercial harvest of lake whitefish in Lake Michigan, 1930–1990.

invasion of the rainbow smelt and the alewife, competition and predation caused the lake herring population to first fluctuate and then crash. Lake herring are now considered rare in Lake Michigan. In Illinois, individuals have been occasionally observed in the commercial chub catch and in the nets of the Illinois Department of Conservation and Illinois Natural History Survey. Unlike populations of yellow perch, chubs, and lake whitefish, the population of lake herring has not rebounded with the decline in the abundance of alewives. The inability of the lake herring populations to recover is not well understood but may be related to predation and competition with exotic species, the lack of broodstock, or a combination of reasons.

Seven species of deepwater ciscos were recognized in Lake Michigan in the late 19th century (Figure 15). The bloater chub is the only one surviving in fishable numbers. The blackfin cisco, longjaw cisco, shortjaw cisco, shortnose cisco, kiyi, and deepwater cisco were first commercially overexploited, then decimated by

the sea lamprey (Wells and McLain 1973). The bloater was the smallest of the seven, and its numbers exploded when the others declined. There is speculation that as the bloater population expanded, it hybridized with surviving individuals of the other species (Becker 1983). During this first period of expansion, the average size of bloaters increased, making them a more sought after commercial fish. After the demise of lake trout, bloaters were the most valuable species caught by Illinois commercial fishermen until the recent increase in the population size and commercial value of yellow perch. Harvest increased as lake trout catches decreased, with the annual bloater harvest averaging 1,200,000 lb from 1947 to 1958 (Baldwin et al. 1979). With the tremendous increase in alewives in the late 1950s, competition and predation caused the population of bloaters to decline steeply. The annual harvest was down to 22,000 lb by 1964 (Baldwin et al. 1979). Catches of bloaters increased into the mid-1970s, though numbers of individuals declined and the sex ratio skewed to 97% female (Becker 1983). Amid fears that a population crash was about to occur, commercial fishing for bloaters was first banned and then controlled under quota systems adopted by various Lake Michigan states.

Since the early 1980s, the bloater population has responded to the steep decline in alewife numbers by increasing rapidly. Bloaters are now the most abundant fish in Lake Michigan. Unfortunately, with the increase in numbers the growth rate has slowed so that most bloaters are too small for human consumption. There is recent evidence that the bloaters have had several poor year classes (Eck and Brown 1991), and poor reproduction makes their future uncertain.

The lake whitefish is one of the most important commercial species in Lake Michigan (Figure 16). Commercial harvest lakewide in the past few years has yielded 5,000,000 to 5,500,000 lb per year (Ebener 1991). Like the other native coregonines, lake whitefish were affected in varying degrees by overexploitation, competition with rainbow smelt and alewives, and predation by sea lamprey. The lakewide harvest dipped to its lowest level in the late 1950s at 25,000 lb (Baldwin et al. 1979). Since the early 1970s, however, the harvest has steadily increased to its present level. Lake whitefish stocks are closely monitored and are managed with quotas. The bulk of the harvest is from the Michigan waters of northern Green Bay, with Wisconsin harvesting the rest.

In contrast to their lakewide status, lake whitefish do not occur in the Illinois waters in substantial numbers. The largest commercial harvest recorded for Illinois was 110,000 lb in 1885. A few thousand pounds were harvested annually in the 1930s (Baldwin et al. 1979).

Other heavily affected native fish species include the burbot, lake sturgeon, emerald shiner, and four species of sculpin. The burbot, a freshwater cod common to the Great Lakes and many northern rivers and lakes, is the only native deepwater predator besides lake trout. Burbot are of minor importance lakewide as a commercial species, with reported catches usually reflecting market demand more than abundance (low market value). Only a few thousand pounds have ever been reported as part of the commercial harvest in Illinois waters (Baldwin et al. 1979).

Burbot populations suffered from sea lamprey predation in the 1940s and 1950s. The populations were then further depressed by alewife predation on larval burbot, and by the late 1960s burbot were considered rare throughout the lake. The combination of effective sea lamprey control and the severe decline in alewife abundance brought on a resurgence in burbot numbers such that they are now common throughout the lake and very abundant in the northern half of Lake Michigan and Green Bay. This is illustrated by the U.S. Fish and Wildlife Service annual index trawling of Lake Michigan. In 1974 the catch averaged less than two burbot per 10-minute trawl, but by 1990 this average had increased to nearly 70 burbot per 10-minute trawl (Eck and Brown 1991). With the increase in the burbot population, the number of deepwater and slimy sculpins captured in trawls has declined, suggesting increased predation by burbot (Eck and Brown 1991). There is also concern about the impact of burbot predation on newly stocked lake trout, especially in the northern end of the lake where burbot concentrations and lake trout stockings are the highest.

The lake sturgeon is the only sturgeon native to the upper Great Lakes. Once abundant throughout Lake Michigan, this species was almost extirpated by commercial fishermen in the 1800s. There are records of lake sturgeon being commercially harvested in Illinois waters in the late 1800s (Baldwin et al. 1979). The first commercial fishermen viewed lake sturgeon as a pest of no commercial value and deliberately destroyed all the lake sturgeon that they caught. Later, the commercial value of lake sturgeon was realized, but because they are slow-growing, slow-maturing fish (females mature in 25 years), they were easily overexploited (Wells and McLain 1973). Small populations still exist in northern Green Bay (Becker 1983). Lake sturgeon are very rare in the rest of Lake Michigan and are protected in Illinois (Johnson 1987).

Emerald shiners were once the most important nearshore forage species in southern Lake Michigan. This was the primary prey species for yellow perch, with all size groups being vulnerable to yellow perch predation. Emerald shiners were so abundant even in the late 1950s that they were considered a nuisance, clogging water intakes of power plants (Wells and McLain 1973). By the early 1960s, emerald shiners had completely disappeared from the lake proper, with a few specimens being caught near the mouths of rivers. This disappearance coincides with the population explosion of alewives and the resulting competition for food and predation on larval emerald shiners. Unfortunately, there has been no noticeable resurgence in emerald shiner abundance even with the steep decline in alewife abundance. The remnant populations continue to be suppressed, possibly by predation by the large yellow perch population.

Four species of sculpin are or were commonly found in the Illinois waters of Lake Michigan. The mottled sculpin is found in nearshore waters. Mottled sculpin abundance or status in Illinois waters is unknown. The slimy, deepwater, and spoonhead sculpins are all found in offshore waters. In the U.S. Fish and Wildlife Service forage trawling surveys, spoonhead sculpins are now very rare. Slimy sculpins were present in low abundance before the alewife decline; their numbers then increased briefly, then declined with the increase in burbot (Eck and Brown 1991). Deepwater sculpins were fairly abundant, but their numbers also decreased with the increase in the burbot population (Eck and Brown 1991). Sculpins are important as a component of the forage base in the offshore waters, with burbot and lake trout preying upon them. Sculpin in turn prey on fish eggs, which may have some impact on burbot, lake trout, and bloater chubs.

Introductions of Exotic Species. Numerous fish, invertebrate, and plant species have been introduced accidentally or deliberately into Lake Michigan (Figure 17). Non-native species enter the Great Lakes primarily via ballast water, solid ballast, navigation channels, and stocking to enhance fisheries (Mills et al. 1993). Although some of these species have a minimal effect on the ecology of the Great Lakes, many others are harmful either to native aquatic species, human populations, or both. Purple loosestrife (*Lythrum salicaria*), Eurasian water milfoil (*Myriophyllum spicatum*), faucet snails (*Bithynia tentaculatum*), and the alga *Cladophora glomerata* probably entered the Great Lakes in ship's ballast and have all negatively affected human populations as well as native habitat. *Cladophora*, introduced in the mid-1800s, and water milfoil cause severe problems by fouling lakefront property, beaches, and swimming areas. The fish diseases furunculosis (*Aeromonas salmonicida*) and whirling disease (*Myxosoma cerebralis*) were probably introduced accidentally during the importation of exotic salmonids, and they now severely affect state and federal hatchery systems. The number of exotic species introduced has increased recently, in part due to the advent of cleaner harbors, clean ballast water dumping restrictions, and increases in trans-Atlantic shipping. Eight European species have entered and become established in the Great Lakes via ballast water in the past 10 years: the ruffe (*Gymnocephalus cernuus*), spiny water flea (*Bythotrephes cederstromii*), fourspine stickleback (*Apeltes quadracus*), round goby (*Neogobius melanostomus*), tube-nosed goby (*Proterorhinus marmoratus*), zebra mussel (*Dreissena polymorpha*), quagga mussel (*Dreissena bugensis*), and the green alga *Nitellopsis obtusa* (Mills et al. 1991). The ruffe, zebra mussel, quagga mussel, round goby, and spiny water flea are expected to have major effects on native species. Only the zebra mussel and spiny water flea are present in Illinois waters, but the ruffe is expected to spread widely and rapidly from its source near Duluth. The ruffe is predicted to compete with yellow perch with potentially devastating effects.

At present, 17% of the fish species in Lake Michigan are exotic (Table 1). Of these species, the sea lamprey, alewife (Figure 18), and smelt (Figure 19) have had the most impact on the native fish species.

Sea lampreys are parasitic fish that feed on the body fluids of other species by attaching themselves to the side of a fish and rasping a hole into the body cavity. They are native to the Atlantic Ocean and probably Lake Ontario. Once again, with the building of canals and locks for interlake and ocean transportation (specifically the Welland Canal in 1932), sea lampreys were able to extend their range westward. The first lamprey noted in southern Lake Michigan was captured off Milwaukee, Wisconsin, in 1936 (Wells and McLain 1979). Lamprey prey included lake trout, lake whitefish, deepwater ciscos, white suckers, burbot, lake herring, yellow perch, and carp. Sea lamprey predation along with commercial overexploitation drove lake trout to extinction by the mid 1950s (Wells and McLain 1979). Burbot and lake whitefish were severely affected. The sea lamprey's effective elimination of all the native large predators indirectly encouraged the population explosion of the alewife.

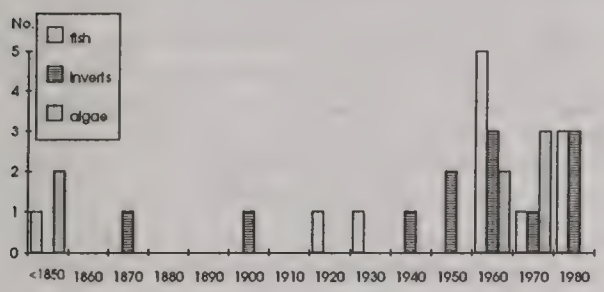


Figure 17. Number of species introduced into Lake Michigan each decade.

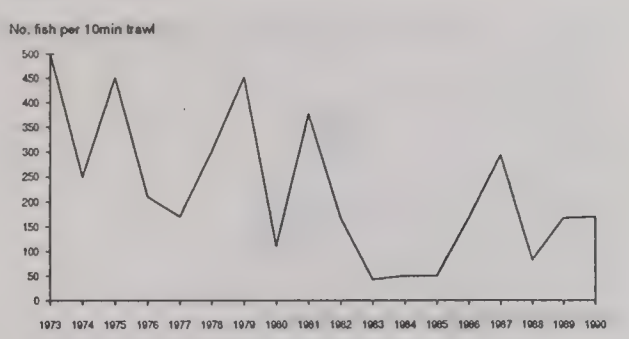


Figure 18. Abundance of alewife in Lake Michigan, 1973–1990 (USFWS trawl data).

By the early 1960s, however, effective sea lamprey controls were in place through a combination of physical and electrical barriers on spawning streams and the chemical control of the larvae in the stream bottoms. This allowed the reintroduction of native salmonids and also the stocking of non-native salmonids. The sea lamprey problem persists and must be kept in check continuously using the controls mentioned above.

Sea lampreys do occur in the Illinois waters of Lake Michigan but not in detrimental numbers. The wounding rate on lake trout examined in fall assessments by state agencies is used to determine abundance and trends in the sea lamprey population. The wounding rates in southern Lake Michigan have been low since the 1970s. Southern Lake Michigan has few tributary streams suitable for sea lamprey reproduction, so most sea lampreys appearing in Illinois waters travel down from the northern end of the lake.

Alewives are native to the Atlantic Ocean and were probably native to Lake Ontario. They spread throughout the upper Great Lakes when canals and locks opened the lakes to shipping. Alewives were first noted in the Illinois waters of Lake Michigan in 1953, and young-of-the-year were first noticed in 1956 (Wells and McLain 1973). By the winter of 1956–1957, commercial fishing nets were clogging with alewives (Wells and McLain 1979). In the absence of sufficient large predators (lake trout and burbot), alewives soon became the most common fish in the lake. After a population explosion in the 1950s, a massive die-off occurred in the late 1960s.

Alewives adversely affected nearly all the native species not already affected by sea lampreys and rainbow smelt through competition for food and

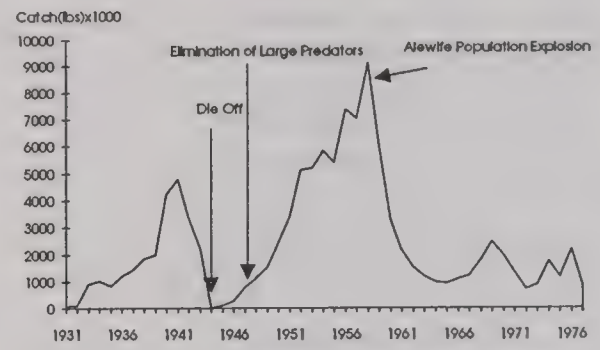

Catch(lbs)x1000
Elimination of Large Predators
Alewife Population Explosion
Die Off
1931 1936 1941 1946 1951 1956 1961 1966 1971 1976

Figure 19. Commercial smelt harvest from Lake Michigan, 1931–1977.

predation on larval fish. Populations of yellow perch and bloater chub were severely depressed. Populations of lake herring and emerald shiners never recovered. State agencies turned to massive stockings of other exotics (chinook and coho salmon, rainbow and brown trout) to try to control this enormous forage base. These stockings, in combination with periods of unfavorable weather (very cold winters), caused the alewife population to first decline to moderate levels, fluctuate, and then collapse in 1979 to the present low levels. With the decline in alewives, some native species have responded by increasing in abundance. Unfortunately, the salmonid sport fishery had become dependent on at least moderate alewife abundance and has suffered accordingly, primarily due to a decrease in larger fish. Emerald shiners and lake herring, which would have replaced alewives in the salmonid forage niche, never responded. Ironically, the recreational and commercial fisheries are currently being manipulated to increase the alewife population.

Table 1. Fish species composition of Lake Michigan, including extirpated species and exotics.

Extant species (n = 65)
Longnose gar (*Lepisosteus osseus*)
Bowfin (*Amia calva*)
Mooneye (*Hiodon tergisus*)
Gizzard shad (*Dorosoma cepedianum*)
Brook trout (*Salvelinus fontinalis*)
Bloater (*Coregonus hoyi*)
Lake whitefish (*Coregonus clupeaformis*)
Round whitefish (*Prosopium cylindraceum*)
Central mudminnow (*Umbra limi*)
Grass pickerel (*Esox americanus vermiculatus*)
Northern pike (*Esox lucius*)
Muskellunge (*Esox masquinongy*)
Lake chub (*Couesius plumbeus*)
Golden shiner (*Notemigonus crysoleucas*)
Striped shiner (*Notropis chrysoscephalus*)
Common shiner (*Notropis cornutus*)
Blackchin shiner (*Notropis heterodon*)
Blacknose shiner (*Notropis heterolepis*)
Spottail shiner (*Notropis hudsonius*)
Rosyface shiner (*Notropis rubellus*)
Spotfin shiner (*Notropis spilopterus*)
Sand shiner (*Notropis stramineus*)
Mimic shiner (*Notropis volucellus*)
Northern redbelly dace (*Phoxinus eos*)
Bluntnose minnow (*Pimephales notatus*)
Fatheaded minnow (*Pimephales promelas*)
Western blacknose dace (*Rhinichthys atratulus meleagris*)
Longnose dace (*Rhinichthys cataractae*)
Creek chub (*Semotilus atromaculatus*)
Northern pearl dace (*Semotilus margarita nachtriebi*)
Quill back (*Carpiodes cyprinus*)
Longnose sucker (*Catostomus catostomus*)
White sucker (*Catostomus commersoni*)
Silver redhorse (*Moxostoma anisurum*)
Golden redhorse (*Moxostoma erythrurum*)
Shorthead redhorse (*Moxostoma macrolepidotum*)
Greater redhorse (*Moxostoma valenciennesi*)
Black bullhead (*Ictallurus melas*)
Yellow bullhead (*Ictalurus nebulosus*)
Channel catfish (*Ictalurus punctatus*)
Trout perch (*Percopsis omiscomaycus*)
Burbot (*Lota lota*)
Western banded killfish (*Fundulus d. menona*)
Brook silverside (*Labidesthes sicculus*)
Brook stickleback (*Culaea inconstans*)
Ninespine stickleback (*Pungitius pungitius*)
White bass (*Morone chrysops*)
Rock bass (*Ambloplites rupestris*)
Pumpkinseed (*Lepomis gibbosus*)
Bluegill (*Lepomis macrochirus*)
Smallmouth bass (*Micropterus dolomieui*)
Largemouth bass (*Micropterus salmoides*)
White crappie (*Pomoxis annularis*)
Black crappie (*Pomoxis nigromaculatus*)
Iowa darter (*Etheostoma exile*)
Striped fantail darter (*Etheostoma f. lineolatum*)
Johnny darter (*Etheostoma nigrum*)
Yellow perch (*Perca flavescens*)
Log perch (*Percina caprodes*)
Sauger (*Stizostedion canadense*)
Walleye (*Stizostechion v. vitreum*)
Freshwater drum (*Aplodinotus grunniens*)
Slimy sculpin (*Cottus bairdi*)
Mottled sculpin (*Cottus cognatus*)

Introduced species (n = 13)
Sea lamprey (*Petromyzon marinus*)
Shortnose gar (*Lepisosteus platostomus*)
American eel (*Anguilla rostrata*)
Alewife (*Alosa pseudoharengus*)
Pink salmon (*Oncorhynchus gorbuscha*)
Coho salmon (*Oncorhynchus kisutch*)
Chinook salmon (*Oncorhynchus tshawytscha*)
Rainbow trout (*Oncorhynchus mykiss*)
Atlantic salmon (*Salmo salar*)
Brout trout (*Salmo trutta*)
Rainbow smelt (*Osmerus mordax*)
Goldfish (*Carassius auratus*)
Common carp (*Cyprinus carpio*)

Extirpated or extremely rare species (n = 11)
Lake trout (*Salvelinus namaycush*)
Deepwater cisco (*Coregonus johannae*)
Kiyi (*Coregonus kiyi*)
Blackfin cisco (*Coregonus nigripinnis*)
Shortnose cisco (*Coregonus reighardi*)
Shortjaw cisco (*Coregonus zenithicus*)
Lake herring (*Coregonus artedii*)
Spoonhead sculpin (*Cottus ricei*)
Deepwater sculpin (*Myoxocephalus thompsoni*)
Lake sturgeon (*Acipenser fulvescens*)
Emerald shiner (*Notropis atherinoides*)

Alewives were never an important component of the commercial fishery in Illinois. Very low market values and lake bottom unsuitable for trawling made it unprofitable to fish for alewives in Illinois.

Rainbow smelt were originally stocked in Crystal Lake in lower Michigan in 1912 as forage for introduced salmon. The salmon stocking failed, and the smelt gained access to Lake Michigan via an outlet from Crystal Lake (Wells and McLain 1973). Smelt became common in the Illinois waters of Lake Michigan by the 1930s (Wells and McLain 1973) and were responsible in part for the suppression of lake herring and lake whitefish populations through competition and predation. A major die-off of smelt in 1944 resulted in the temporary increase in abundance of these two species (Wells and McLain 1973). Smelt populations increased again through the 1950s. Then the population declined and has since fluctuated in moderate numbers compared to the early 1940s (Wells and McLain 1973).

Rainbow smelt are now an important component of the forage base, being utilized by all of the salmonids, burbot, and yellow perch. Lakewide, rainbow smelt have supported a commercial fishery, with the bulk of the harvest by trawlers in Green Bay. Smelt are of only minor importance to the Illinois commercial fishery, with harvest in the 1950s and in the 1970s ranging from 1,000 to 42,000 lb (Baldwin et al. 1979). Since the 1930s, a spring recreational fishery has evolved during the inshore spawning migration.

A number of non-native salmonines have been deliberately introduced into the Great Lakes (Figure 20), and one species was accidentally released. The pink salmon, originally from the Pacific Northwest, had established itself in Lake Superior in 1956 (Becker 1983). It has since spread throughout the upper Great Lakes and is the only species of Pacific salmon in the Great Lakes that is completely self-sustaining. It is also the smallest salmon, with only a two-year life span and an average weight at maturity of 1.5 pounds (Becker 1983). Occasionally, one is caught off Illinois (Horns and Brofka 1992). They are of little recreational value and compete for forage with more desirable species. Populations of all other salmonids, including the native lake trout, are maintained by stocking. Although lake trout are the most stable predator population, because they are generalist feeders, their numbers are greatly outweighed by stocking of the other, non-native salmonids.

Atlantic salmon are native to the Atlantic Ocean and Lake Ontario. They have been introduced into Lake Michigan in relatively small numbers (17,000 to 25,000 per year). Wisconsin is currently stocking a landlocked strain in the Root River (Racine County) only 15 miles from the Illinois state line (Coshun 1991). Every year a few are caught off the Illinois shoreline (Horns and Brofka 1992). Atlantic salmon are highly prized sport and commercial fish in their native range. Because of their scarcity they are little more than curiosities in Lake Michigan.

Brown trout, originally from Europe, have been stocked in large numbers (1.6 million average per year), mostly by Wisconsin since the 1960s (Keller 1991). Illinois also stocks brown trout. They are a valuable sport fish often caught in Illinois by shore fishermen. The average catch between 1986 and 1991 was 7,600 per year, excluding the small charter catch; 70% of this catch is by shore fishermen (Horns and Brofka 1992).

Rainbow trout, originally from Pacific Ocean drainages, have been stocked in Lake Michigan in fairly

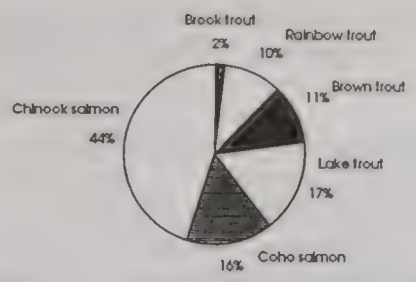


Figure 20. Composition of average annual salmonine stockings in Lake Michigan, 1985–1990.

large numbers (1.5 million average per year) since the 1960s (Keller 1991). In the past 10 years, specific strains of steelhead (ocean run) rainbow trout have been stocked in Lake Michigan. Rainbow trout are prized sport fish because they grow fast and are very active when hooked. Illinois is totally dependent on its own and its neighbor's stocking. The average noncharter Illinois harvest between 1986 and 1991 was 5,000 per year (Horns and Brofka 1992).

Coho salmon were first introduced into Lake Michigan in 1966. They are originally from the West Coast, and the eggs used in the original stocking came from Oregon and Alaska. Large numbers are stocked (2.3 million average per year), mostly by Michigan (Keller 1991). Illinois and Wisconsin also stock substantial numbers. Coho are a very popular sport fish and provide an excellent spring and early summer fishery each year off Illinois. The noncharter average harvest in Illinois waters between 1986 and 1991 was 65,000 per year (Horns and Brofka 1992).

The largest Pacific salmon, the chinook or king, has been stocked at the rate of 5.4 to 7.7 million annually in recent years. Its maximum weight approached 50 pounds in the early 1970s, but the average size has declined since then. Chinook salmon have been plagued by disease, and spring die-offs of varying severity have been observed since 1988. They are highly prized by sport fishermen and still occasionally reach weights of more than 30 pounds. Stocking reductions designed to enhance the alewife population have focused on this species because it has a four-year life span, with three and one-half years spent in Lake Michigan. Alewives are by far a chinook salmon's preferred prey. From 1986 to1991 the noncharter average annual catch of chinook salmon in Illinois waters was 16,000. The high point during this period

was in 1986, with a catch of 30,000, and the low point was in 1988, with a catch of 10,000 (Horns and Brofka 1992).

All the Pacific salmon listed are valuable sport and commercial fishes in their native range. Unfortunately, organic chemical contamination of their tissue has caused a ban on the commercial sale of these fishes originating from Lake Michigan, and all the Great Lake states have health advisories concerning personal consumption of sport fish.

The white perch is native to the Eastern Seaboard region of North America and Lake Ontario. With the building of canals and locks, this species has slowly expanded its range westward, arriving off the coast of Illinois probably in 1988 (Hess 1991). It has since established a population of unknown size in the Calumet Harbor/Lake Calumet complex on Chicago's south side. Specimens have been collected or observed as far north as Waukegan. The effect of this new fish on native species is unknown. However, in Lake Erie white perch had a definite adverse effect on the yellow perch population in the western basin. Because Lake Erie is very different from Lake Michigan, it is debatable whether white perch will have the same effect here.

The threespine stickleback is native to the Eastern Seaboard region of North America and to Lake Ontario. It also expanded its range westward, probably arriving off the Illinois shoreline in 1988. Individuals and small schools have been trawled or seined by both the Illinois Natural History Survey and Illinois Department of Conservation. The size and status of the population in Illinois waters and its effects on native sticklebacks or other fishes are unknown.

Common carp were introduced into the Great Lakes to create a fishery and for nostalgic reasons (because they were familiar to European settlers). Within a few years of their becoming established, their destructive habits caused people to doubt the wisdom of their introduction. Carp compete with native species for food, and young carp probably serve as a minor forage species. Their major impact is due to their benthic foraging, which disrupts vegetation beds and increases siltation in the water column.

The first commercial record of the harvest of carp lakewide was in 1893, with a catch of 2,000 pounds (Baldwin et al. 1979). Since then, carp have become abundant throughout the shallow waters of Lake Michigan. Carp are common in all the harbors along the Illinois coastline. The actual status and relative size of the carp population in Illinois waters is unknown. Only a few thousand pounds of carp have been harvested commercially in Illinois waters since 1910 (Baldwin et al. 1979). Commercial records lakewide reflect consumer demand more than abundance. The sale of carp caught in Lake Michigan has been banned since the 1970s because organic chemical contamination of the tissue was determined to be high. Carp are routinely in the greatest risk group in various state health advisories. Nevertheless, carp are a minor recreational fish, fished deliberately for food in the harbors and power plant discharge channels along the shoreline (Horns and Brofka 1992).

Grass carp are a native of Asia and, as the name suggests, feed primarily on vegetation. Sterile grass carp have been used for aquatic vegetation control in many states (Becker 1983). In the mid 1980s, the Chicago Park District stocked them in some harbors. A few have since been observed or electrofished and collected by Illinois Department of Conservation personnel. The status and population size of this species in Illinois waters is not known, but the population is not thought to be large.

Zebra mussels are an exotic species that entered Lake St. Clair via the ballast water of an oceangoing ship. They were introduced in 1986 and have rapidly spread throughout the Great Lakes and major inland waterways of eastern and central North America. Several characteristics of zebra mussels make them well-suited to colonizing new areas. Zebra mussels release large numbers of eggs and sperm into the water column (40,000–1,000,000 eggs per adult female). External fertilization of the eggs produces planktonic larvae, called veligers, which remain in the water column for approximately three to five weeks. The microscopic veligers may be transported unknowingly by recreational water users (e.g., in bait buckets and live wells) and are also dispersed by water currents. Following the brief planktonic period, zebra mussels settle out of the water column and attach themselves with byssal threads to nearly any available substrate. Substrates range from inanimate objects such as rocks, buoys, and breakwalls to aquatic vegetation and hard-shelled animals (clams, snails, and crayfish).

Zebra mussels can have tremendous ecological and economic impacts on the systems in which they become established, both as a result of their colonization of hard surfaces and their feeding strategy. Zebra

mussels are generalist filter feeders, removing microscopic particles (5–450 mm) from the water column. Undigested material is ejected in a mucoid ball known as psuedofeces. The net effect is a depletion of suspended organic material and an increased rate of sedimentation.

Removal of suspended organic material due to zebra mussel filtering activity can lead to considerable clearing of the water column (Figure 21). For example, water clarity increases between 1988 and 1991 of 77% in the western basin of Lake Erie and 20% in the west-central basin have been attributed to zebra mussels (Leach 1993). Water clarity in the southern basin of Lake Michigan may also be increasing, as indicated by Secchi disk measurements. However, this figure must be interpreted with caution given the limited data currently available for years preceding the arrival of the zebra mussel.

Zebra mussels may affect the base of the food chain by removing microorganisms such as algae and small zooplankton, which could decrease the number of large-bodied zooplankton on which forage fish (e.g., alewives, bloaters and smelt) prey. Sport fish such as trout and salmon could ultimately be affected by diminished forage fish populations. The reduction of suspended particles can result in increased light penetration, which can stimulate macrophyte growth. Native clams and snails suffer reduced growth rates and mortality as zebra mussels colonize their shells. Other benthic organisms such as chironomid larvae, amphipods, and planaria can benefit from the deposition of organic matter to the benthos.

Zebra mussels also affect water users. Industries and utilities experience clogging and increased expense related to control programs as zebra mussels settle on intake pipes and internal structures (Table 2). Chlorination is frequently used to kill mussels or prevent the larvae from settling. This often involves retrofitting a plant with costly chlorine feed systems, and subsequent chemical costs can be high. Industries drawing water from southern Lake Michigan have cited chemical costs during the zebra mussel reproductive season of $1,000/day. Recreational water users are also affected by zebra mussels. Boat hulls and docks can be encrusted with mussels. There has been at least one instance of a Chicago-area boater experiencing engine damage due to clogging and subsequent overheating. In areas with large populations of mussels, the sharp shells of dead zebra mussels may litter beaches.

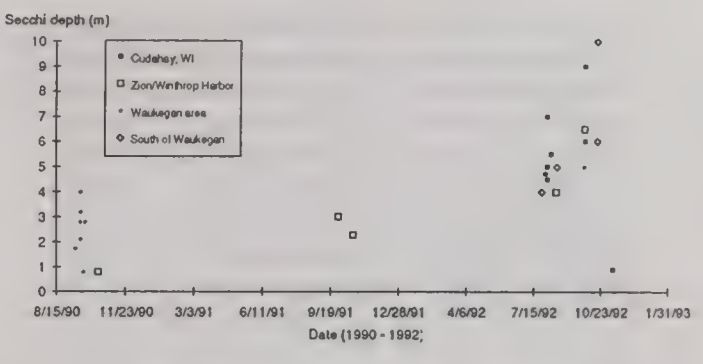


Figure 21. Water clarity measurements at various locations in Lake Michigan, 1990–1992.

Table 2. Economic costs of retrofitting (based on Nelson 1992).

Chicago	Chemical feed to intake (2 plants)	$248,000
	Projected chemical feed to three cribs	$5,870,000
Evanston	Chemical feed to three intakes	$1,000,000
Wilmette	Chemical feed to two intakes	$230,000
Glencoe	Chemical feed to intake	$150,000
North Chicago	Chlorine feed to intake	$150,000
EPRI	Average cost of retrofitting	$250,000–400,000
Waukegan	Projected cost of retrofitting for heat treatment	$400,000
Zion	Projected cost of retrofitting for heat treatment	$500,000

Abiotic Factors. Soil erosion from farm land and forested land can damage aquatic habitats, foul recreational waters, and increase the cost of processing potable water. Siltation of spawning beds may be implicated in the decline of whitefish stocks and the inability of stocked lake trout to reproduce. In 1982, soil erosion rates along the Illinois shoreline were the highest in the Great Lakes drainage basin, averaging 3–4 tons per acre per year (Colborn et al. 1990). The cost of this erosion is seen not only in damage to aquatic organisms in Lake Michigan but also as direct economic effects on agriculture through loss of arable land. Erosion is exacerbated by fluctuating lake levels, which reached a historic low of 575.5 feet in the mid 1960s and a recent historic high of 581.5 feet in the mid-1980s.

Toxic chemicals have entered the Lake Michigan watershed from several sources, particularly agriculture

and industry. The 11 critical pollutants identified by the International Joint Commission are herbicides (dioxin, furan), insecticides (DDT, dieldrin, mirex, toxaphene), industrial by-products (hexachlorobenzene, mercury, PCBs) and by-products of combustion of fossil fuels (benzopyrenes, lead) (Colborn et al. 1990). Concentrations of these chemicals in Lake Michigan have led to its classification as the second most degraded Great Lake following Lake Ontario. Concentrations of DDT, PCBs, and dieldrin are most severe in the southern end of the lake (Colborn et al. 1990). Local concentrations of these toxins in certain locations prompted the International Joint Commission's Great Lakes Water Quality Board to identify 42 Areas of Concern. Ten of these areas lie in Lake Michigan; one of the most highly degraded of these sites lies within Illinois waters at Waukegan Harbor. Several chemical and manufacturing industries are concentrated near Waukegan Harbor, and the sediments in the harbor are heavily contaminated with PCBs and heavy metals. Cleanup of the site began in 1991 and will continue for several years. Accumulation of toxins through the food chain concentrates them in the flesh of piscivorous fish. Consequently, fish consumption advisories are published annually by the Illinois Department of Conservation in the sport fishing regulation handbook. For the past several years, the advisories for Lake Michigan have recommended zero consumption of "Group 3" fish (brown trout and lake trout over 23 inches, chinook salmon over 32 inches, and all carp and catfish), and minimal consumption of "Group 2" fish (brown trout less than 23 inches, lake trout 20–23 inches, chinook salmon 21-32 inches, and coho salmon over 32 inches).

Phosphorous and nitrogen loading, both associated with use of fertilizers and increased surface run-off, have changed the composition of algal populations in the lakes. The increase in nitrogen levels in southern Lake Michigan has been implicated in changes in the zooplankton community (Scavia et al. 1986). Levels of sulfate, cadmium, magnesium, sodium, potassium, chloride, and total dissolved solids have all increased in the lake since the 1800s (Colborn et al. 1990). Silica concentrations declined in the 1950s and 1960s, with a consequent shift in diatom population levels.

Isolated point sources of toxic pollutants are often the consequence of accidents such as rail car derailment (see Colborn et al. 1990). Contamination of the groundwater in Illinois has also led to pollution of nearshore waters. Oil pollution has so far been limited in the Great Lakes, but the potential for a tanker spill is a source of increasing concern. Agencies in Chicago have developed emergency scenarios to deal with a potential spill, which because of the enclosed nature of the lake could easily foul vast areas of shoreline. Illinois is the home of one of 14 nuclear generating stations in the basin, and this station has one of the three worst maintenance and safety records in the nation. The consequences of a nuclear accident to the aquatic system, let alone the human population in Chicago, are inestimable.

Future of Lake Michigan

In recent decades, our understanding of the consequences of human activities on the Lake Michigan ecosystem has led to many improvements. Fishing regulations and quotas have reduced fishing pressure, leading to the recovery of several fish stocks. Awareness of problems associated with exotic species has resulted in more careful review of proposals to stock new fish species. The problems caused by zebra mussels throughout the Great Lakes basin have stimulated the imposition of ballast water dumping restrictions, which may ultimately reduce the flow of new species into the ecosystem. In 1978, the Great Lakes Water Quality Agreement adopted a philosophy of zero discharge of toxic chemicals into the Great Lakes watershed. Since 1978, many chemical pollutants have been banned and discharges have been reduced. However, many persistent chemicals remain in the sediments and water and continue to be accumulated throughout the food chain.

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FLOWING WATERS

SUMMARY

• Substantial numbers of species of fish, amphibians and reptiles, and invertebrates that inhabit running waters have been extirpated from Illinois during the 20th century, and many more are threatened with elimination from the state. Of the species in Illinois at the start of the century, about 19% of the fish, 34% of the amphibians and reptiles, 55% of the freshwater mussels, and 22% of the crayfish have been extirpated or are threatened by extinction in Illinois.

• Similar information is not available for other groups of organisms that inhabit flowing waters. This is especially troublesome for two groups—aquatic insects and plants (algae and macrophytes)—that are functionally extremely important in stream ecosystems.

• Recent evaluations of the biotic integrity (or health) of Illinois' streams and several long-term studies suggest that it should not be surprising that such a high proportion of the state's flowing water fauna should be either extirpated or in danger of extinction in Illinois. When the condition of Illinois streams is assessed according to biological criteria, the proportion of stream miles of moderate to very poor quality greatly exceeds the proportion rated as good to excellent. Unfortunately, similar statewide evaluations of the quality of Illinois' streams were not performed in past decades. Nonetheless, earlier workers (e.g., Ross [1944]) who sampled extensively throughout the state lamented the overall quality of streams in Illinois and noted that a very high proportion of them had been appreciably manipulated. Interestingly, Ross (1944) did not refer to effects of urbanization, especially the effects of organic effluents such as sewage, as being major causes of poor stream quality. Rather, he considered landscape manipulations within watersheds (e.g., removal of riparian vegetation, agricultural practices leading to increased erosion from farmlands, channelization of streams) to be the major factors affecting stream quality. We do not have data on long-term trends in many land-use practices within watersheds and are, therefore, unable to associate such trends with current assessments of stream quality.

• Despite the comments of Ross (1944), discharge of sewage effluents into streams strongly affected stream quality, especially in the first 60–70 years of this century. Two long-term studies of fish populations in the Illinois River and in the streams in Champaign County have documented improvements in stream quality (based on the status of fish populations) over the past 30 years that are likely the result of improvements in the treatment of sewage discharged into streams. Especially noteworthy are marked improvements in functionally and economically important piscivorous populations (e.g., smallmouth and largemouth bass, channel catfish) in both studies.

• The current status of fish populations in the Illinois River and in the streams of Champaign County indicates, however, that significant problems persist. In the upper Illinois River, bottom-dwelling fishes have poor body condition and a high incidence of external abnormalities, suggesting a continuing problem with sediments, which are known to be toxic to the invertebrates on which these bottom-dwelling fishes feed. In Champaign County, the frequency with which species that are tolerant of poor habitat quality are encountered has increased over the past 90 years.

• Although improvements in some fish populations in several systems have been observed, similar improvements have not been noted for mussel populations in four rivers in east-central Illinois for which there are long-term records. In all four rivers, large reductions in populations of most mussel species have occurred over the past 40 years, apparently due to increased siltation and loss of suitable habitat.

• Mussel populations in Illinois' largest rivers, the Mississippi and the Illinois, face similar threats but also must contend with exploitation by humans for the cultured pearl industry. Commercial harvest of mussels in these rivers increased dramatically between 1987 and 1990. In the absence of fundamental information on birth and death rates for harvested populations, it is unclear whether these populations can sustain such high rates of exploitation.

• Similarly, it is unclear whether commercially harvested fish populations in the Mississippi, Illinois, Kaskaskia, and Wabash rivers are being overexploited, although the catch of most species has been relatively stable over the past 20 years.

• Mussel populations may also be adversely affected by exotic species, such as the zebra mussel and the Asiatic clam. Similar problems face other invertebrates (e.g., crayfish), fish, and macrophytes. Perhaps more important than their effects on individual species populations, exotic species can also markedly affect ecosystem structure and function. Little information exists for any of these effects in Illinois.

• Numerous areas requiring additional research are evident from our analyses. The following general areas are in particular need of immediate attention:

1. Considerably more data are needed on the population dynamics of harvested species so that allowable harvest rates can be better determined.

2. Research on the anticipated effects of exotic species on species populations and ecosystem-level properties is needed to develop management plans.

3. Long-term studies need to be established on functionally significant groups in lotic systems (e.g., aquatic insects, crayfish, plants) for which long-term data are scarce. Long-term studies on other populations (e.g., fish, mussels) need to be extended to include a broader range of flowing-water systems represented in Illinois.

4. Much more research on the ecology of large rivers is greatly needed. Considerably less is known about the mechanisms affecting the structure and function of such systems relative to smaller streams. In particular, the effects of manipulations within the floodplain (e.g., levee construction) and within the stream channel (e.g., navigation dams, navigation traffic) need further attention. An experimental approach, although difficult to take on such large systems, would be advisable in many circumstances. For example, the destruction of levees on several large rivers by the Great Flood of 1993 provides a unique opportunity to experimentally address the effects of such structures on population-, community-, and ecosystem-level properties. Appropriate agencies should consider appropriating funds for such research immediately. There is an excellent opportunity to coordinate such research with ongoing studies such as the Long Term Resource Monitoring Program on the Illinois and Mississippi rivers.

• Restoration, protection, and management of Illinois' streams requires the adoption of a large-scale perspective (i.e., watershed-level or basin-level) regarding the structure and function of stream ecosystems. Stream reaches tend to be managed as though they were independent of upstream or downstream reaches within the watershed or drainage basin. This practice ignores virtually everything that is known about how stream ecosystems work. Any given segment of stream is strongly influenced by things occurring within the segment *and* by things occurring upstream of the segment in the watershed and downstream (e.g., from damming; spawning migrations of fish). Few perturbations to streams (e.g., sewage effluents) can be considered to be processed locally within a stream segment and, consequently, to have little influence on downstream segments. Most other perturbations that appear to be markedly affecting Illinois streams (e.g., land-use practices affecting stream morphology, sedimentation, and inputs of polluting chemicals such as plant nutrients, herbicides, pesticides, and other toxic chemicals) cannot be considered to be "processed" within a given stream segment, in part because the inputs (of sediments, chemicals) generally are not localized and because many inputs (e.g., sediments) are more or less biologically inert and, therefore, are not "processed" at all.

An expanded lateral perspective should also be adopted. Larger streams are intimately connected in terms of morphology, hydrology, structure, and function with their floodplains as well as with upstream and downstream reaches within the drainage basin. Management of large rivers in Illinois and elsewhere has expressly attempted to uncouple this link between the river and its floodplain, largely through the construction of levees and dams. The consequences of such attempts can be disastrous for humans (e.g., the Great Flood of 1993) as well as for the biota of large rivers, although more research in this area is urgently needed.

The bottom line is that management of a large stream, for example, must consider what is occurring *throughout* the drainage basin, especially upstream and immediately downstream of the area of interest and laterally within the floodplain. Therefore, management of large streams requires management of their tributaries throughout the drainage basin. Adoption of such a perspective will not be easy. For instance, the structure, function, and utilization of drainage districts will have to be dramatically altered. However, *only* through the adoption of such a perspective will we be able to improve stream quality and preserve and protect existing high-quality streams in Illinois.

INTRODUCTION

Illinois contains over 26,000 miles of flowing waters, which constitutes about 19% by area of the total surface water in the state. Illinois is bordered on the west and south by two of the largest and most celebrated rivers in the country, the Mississippi River and the Ohio River, respectively. Within its boundaries, the state contains a striking diversity of flowing-water environments, including small, spring-fed, coldwater creeks; stony-bottomed coolwater and warmwater streams; and largely soft-bottomed, warmwater streams. Such diversity of habitats has helped to foster a diverse flowing-water fauna and flora within the state.

This diversity of stream environments is not broadly distributed throughout the state; rather, it is concentrated in a small subset of the state's flowing-water systems. The vast majority of the streams in Illinois have been highly manipulated, either directly, by alterations within the stream, or indirectly, by modifications of the surrounding landscape, or both. Direct manipulations of stream habitats are often highly visible, such as construction of dams and the straightening or channelization of stream reaches. In fact, in many areas of the state, a significant proportion of smaller streams have been constructed entirely by humans to provide more effective land drainage and more suitable conditions for agriculture. Illinois streams have also been indirectly affected by land-use practices within watersheds, which can affect instream habitat (e.g., by sediment loading from the adjacent landscape) as well as the riparian zone and floodplain, which are integrally connected, both functionally and structurally, to the streams. Because of such manipulations, streams in areas of intensive agriculture in Illinois are perhaps more homogeneous today than they were prior to settlement (see Ross 1944).

This report is loosely organized into five main sections. The first describes some aspects of the existing physical and biological characteristics of Illinois' flowing waters, including their utilization for recreational purposes. The second considers trends in land use within watersheds, instream manipulations, and human use of biotic resources in streams. The third section addresses trends in the composition and abundance of several important biotic components of stream systems. The fourth considers ongoing restoration and protection activities related to Illinois' streams. The final section contains a brief summary and recommendations for research and management.

GENERAL PHYSICAL CHARACTERISTICS

Drainage Basins

The streams of Illinois (Figure 1) occur within 10 basins (Figure 2) that are drained by the following major river systems: the Rock; the Fox and Des Plaines; the Spoon; the Kankakee, Vermilion, and Mackinaw; the LaMoine; the Sangamon; the Embarras and Vermilion; the Kaskaskia; the Little Wabash; and the Big Muddy and Shawnee. Streams in the drainage formed by the Embarras and Vermilion rivers and in the Little Wabash basin flow into the Wabash River, and streams in the Big Muddy and Shawnee basin flow into the Mississippi River or the Ohio River. Streams in all other basins flow into the Mississippi River, many of these via the Illinois River, which cuts diagonally across the state and empties into the Mississippi near Alton.

Figure 1. Illinois lakes and streams.

Figure 2. Illinois drainage basins.

Riparian Land Cover

Streamside riparian buffer strips are an integral part of rivers and streams. They stabilize banks, reduce erosional input, filter agricultural runoff, and protect streams from excessive nutrient loading. Prior to human settlement, the vegetation along Illinois' streams was predominantly forest. With the onset of large-scale agriculture has come a shift in this vegetative cover. Though forested areas and areas of mixed woody and herbaceous vegetation still dominate, the amount of area covered by grasses and cultivated crop fields has increased. Table 1 shows the percentage of cover of various types within 82 ft (25 m) of rivers and streams that drain 10 square miles or more within Illinois.

The sources for the land cover (vegetation) information were aerial photographs taken for the Agricultural Stabilization and Conservation Service. After the photographs were interpreted, the findings were entered into the Illinois Streams Information System database. For stream banks within Illinois, eight types of land cover were determined: forested areas (> 45% canopy), areas of mixed vegetation (< 45% canopy), grassy areas (noncultivated), agricultural areas, urban or developed areas, disturbed or barren areas, reservoirs, and other water areas. For the present report, forested areas and areas of mixed vegetation, grassy areas (noncultivated) and agricultural areas, and reservoirs and other water areas were combined to form a total of five coverage types (Table 1).

There are large differences among the 10 drainage basins in the percentages of forest/mixed and agriculture/grass buffer strips (Table 1). In the heavily forested southern portion of the state, 81% of the buffer strip area has forest/mixed coverage and only 11% agriculture/grass coverage. In contrast, in the agriculturally dominated Rock River basin, only 55% of the buffer strip coverage is forest/mixed, and 43% is agriculture/grass.

Channelization

Channelized streams are extremely common in Illinois, largely as a result of agricultural demands throughout the state (Figure 3). Channelization has been widely practiced throughout the United States and elsewhere (e.g., see Hortle and Lake 1982), largely for improving drainage from agricultural lands and for flood control (i.e., enhancing runoff after storms). However, channelization can have substantial adverse effects on physical and, consequently, biotic parameters in streams and the adjacent riparian zone. Among the major effects of channelization are a reduction in habitat diversity for invertebrates and fish (from a variety of causes) and increases in bank erosion and sediment transport. Generally, channelization results in reductions in the abundance and diversity of benthic invertebrates and fish (Hortle and Lake 1982, Henegar and Harmon 1973), and these negative effects may persist for very long periods after the initial channelization of a stream (Arner et al. 1976).

Ownership of Streamside Land

Public ownership of streamside land is extremely important for the promotion of environmental education and outdoor recreation in Illinois. Public ownership of these areas allows for the creation of preservation and conservation areas as well as the generation of revenues for other state interests. Currently the state owns 15% of the land bordering streams that drain 10 square miles or more. There are large differences among basins in the amount of publicly owned land along streams. For example, in the basin of the Fox and

Table 1. The percentage of land in each land-use category within 82 feet (25 m) on either side of streams in each of the 10 major drainage basins in Illinois.

	Land-use category				
Basin	Forest/mixed	Agriculture/grass	Urban	Water	Barren
Rock	54.7	43.0	0.76	0.78	0.17
Fox	66.0	24.7	3.50	2.18	1.04
Kankakee	43.9	53.2	0.22	1.08	0.47
Spoon	70.0	26.9	0.03	1.81	0.05
Sangamon	59.3	35.4	0.05	3.51	0.02
La Moine	75.9	21.0	0.16	1.16	0.56
Kaskaskia	76.2	21.4	0.36	3.26	0.30
Embarras	65.7	29.0	0.08	0.65	0.10
Little Wabash	76.4	19.6	0.02	1.60	0.08
Big Muddy	81.2	11.2	0.06	3.05	0.39

Des Plaines rivers, nearly 40% of the land bordering streams draining 10 square miles or more is owned by the state, whereas in the Little Wabash River basin only 5.9% is considered public land (Figure 4).

Recreational Canoeing

Another important aspect of publicly owned streamside areas is the accessibility for specific uses such as recreational canoeing. Again, there are considerable differences among basins in the amount of canoeable streams (Figure 5). Percentages of stream length that are canoeable vary from 20.9% in the basin of the Fox and Des Plaines rivers to 0.1% in the Little Wabash River basin. These percentages are calculated by summing the lengths from the uppermost public entry points on streams within the basin downstream to either the stream's end or the point at which it exits the basin. Because traditional canoe access points on public or quasi-public land could not be included in this data set, it is likely that Figure 5 underestimates the amount of canoeable streams in each basin.

CURRENT STATUS OF BIOLOGICAL COMMUNITIES

Several governmental agencies in Illinois have given high priority to activities aimed at the protection of aquatic habitats and their biota. Two recent studies have sought to identify the state's most biologically significant streams.

The Biological Stream Characterization (BSC) is a stream-quality index developed by the Illinois Department of Conservation and the Illinois Environmental Protection Agency to categorize streams (Hite and Bertrand 1989). The BSC is based largely on fish and aquatic macroinvertebrate diversity and relies primarily on the Index of Biotic Integrity (Karr et al. 1986). This index assesses the biological condition of streams by using a range of fish community attributes that fall into three broad categories: species composition, trophic composition, and fish abundance and condition.

In the BSC, stream segments are categorized from "A" to "E." "A" streams are considered to be in excellent condition, comparable to the pristine conditions that existed in Illinois prior to human disturbance. "B" streams are in good condition and typically support important game fishes, but overall species diversity is below expectations. "C" streams are in fair condition, typically with reduced diversity and a game fish population consisting primarily of bullheads, sunfishes, and carp. "D" streams are in poor condition and have notably reduced diversity, with the community dominated by environmentally tolerant species. The "E" category comprises very poor streams that support only a few individuals of the most environmentally tolerant species of fishes and macroinvertebrates.

As of December 1988, 614 stream segments had been evaluated, representing approximately 29% of the stream miles in Illinois (Hite and Bertrand 1989). Only 4% of the stream miles studied were classified as type A (Figures 6 and 7). Unfortunately, 66% of the stream

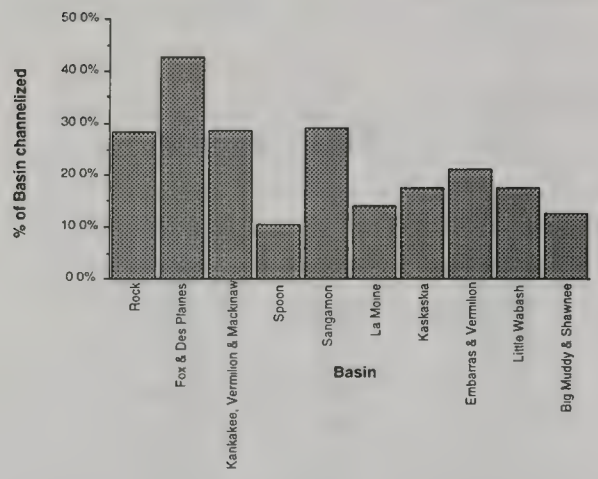


Figure 3. Percentage of each basin's total stream length that has been altered through channelization. Data were collected from 1981 to 1990 and cover only those streams that drain an area of 10 sq. mi. of the basin or more and; therefore, the data most likely underestimate the basin-wide percentage of channelized streams. Channelization data were collected from several sources: (1) an Illinois Department of Conservation (IDOC) Division of Fisheries report titled "Channelized Streams and Ditches of Illinois," (2) county highway maps from the Illinois Department of Transportation (IDOT), (3) Agricultural Stabilization and Conservation Service (ASCS) aerial photogrtaphy slides, and (4) the most recent U.S. Geological Survey (USGS) 7.5-minute topographic maps. The IDOC report listed the lengths of channelized stream segments per county but did not give the location. Channelized stream segments were located using county highway maps, ASCS aerial slides, and USGS 7.5-minute topographic maps. Ground truth surveys in the Sangamon River basin were then carried out to verify the location accuracy of several of these stream segments.

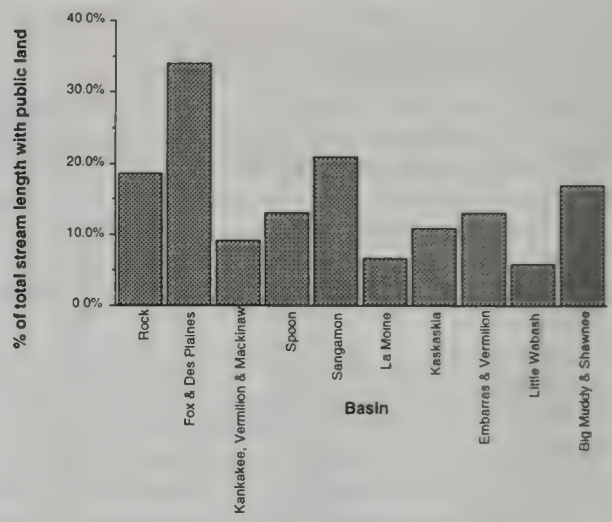


Figure 4. Percentage of stream length that is bordered by public land in each basin. To assess the extent of accessible public land holdings along Illinois' streams, the most recent county plat books and government agency publications about land holdings were used to identify owners, who were then contacted for more specific information about these sites. The Sangamon Basin was the first completed by the Illinois Streams Information System (ISIS). It was the testing ground for surveys used in the other basins. Included in the Sangamon Basin are areas such as privately owned golf courses, scouting camps, country clubs, utilities, sewage disposal areas, landfills, cemeteries, schools, churches, and hospitals. After the Sangamon, the data type was more specifically defined as publicly owned and accessible to the general public for recreation. Basins other than the Sangamon are limited to these types of areas and do not include pseudo-public areas or areas unavailable for recreation use. This graph represents only those streams that drain 10 sq. mi. or more of area within the boundaries of Illinois. The data here can be considered accurate as of the date associated with the source; however, public ownership of land changes slowly. In addition, certain areas of the state have been previously surveyed on a more local level (by county agencies, etc.) as to public land holdings and are, therefore, probably more complete.

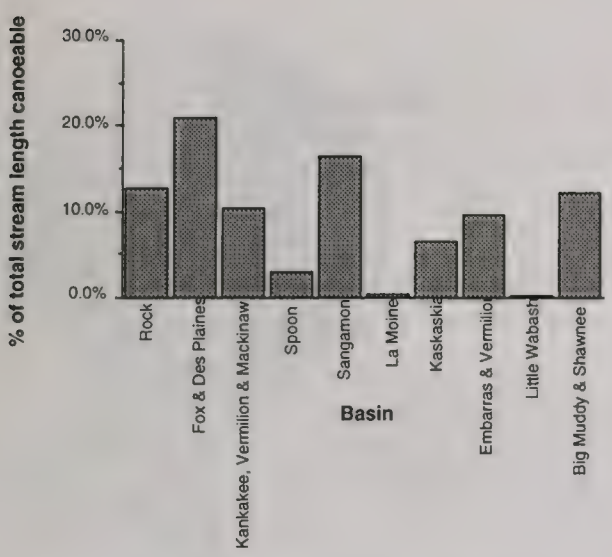


Figure 5. Percentage of each basin's total length of rivers and streams that can be canoed after being accessed at a publicly owned streamside area. This graph includes only those streams that drain 10 sq. mi. or more of area within Illinois. For the purpose of this figure, it is assumed that a stream can be canoed from the point of entry until the point at which it either ends or exists the basin. Although the Mississippi, the Illinois, and the Wabash rivers can be canoed, their lengths are not included as canoeable in this graph. The canoeable lengths of these rivers within Illinois from the uppermost public access site to the point where they exit the state are 578.8, 272.4, and 190.4 miles, respectively. From this graph it appears that a very small percentage of Illinois' potentially canoeable streams are being utilized. However, this graph underestimates the availability of canoeable areas in Illinois because it does not include quasi-public and private access points that are frequently used by the public. However, this figure and Figure 4 demonstrate that in some Illinois basins such as the LaMoine and Little Wabash the availability of public recreation sites and canoeable stream areas is severly limited and public land purchases may be necessary to increase accessibility.

miles were rated C or lower and have been severely degraded (Figures 6 and 7).

In a second study, described in a report titled "Biologically Significant Illinois Streams: An Evaluation of the Streams of Illinois Based on Aquatic Biodiversity" (Page et al. 1992), the list of streams identified in the BSC as biologically significant was expanded by considering additional data on biodiversity. The expanded list identifies streams and stream segments that support populations of federal or state threatened, endangered, or "watch list" species of fishes, mussels, crayfishes, and vascular plants, as well as those with the highest fish (BSC "A" streams) and mussel diversity. Streams were assumed to support threatened, endangered, or watch list species if the species have been observed there since 1980. One hundred eight streams supporting threatened, endangered, or watch list species or supporting a high diversity of mussels were identified. These streams, in addition to the 24 streams identified as "A" streams in the BSC classification, bring to 132 the number of biologically significant streams and stream segments currently recognized in Illinois (Figure 8).

TRENDS IN WATERSHED CHANGES AND RESOURCE USE

Land Use in Watersheds

The structure and function of flowing water ecosystems are intimately related to the geology, terrestrial vegetation, and many additional aspects of the surrounding landscape (Hynes 1975, Vannote et al. 1980, Naiman and DeCamps 1990). In particular, it is becoming increasingly recognized that the nature and extent of riparian vegetation adjacent to running waters can profoundly influence numerous physical, chemical, and biotic characteristics of streams and rivers, such as channel morphology and streambank stability, inputs of solar radiation (which influences instream primary production and thermal regimes), inputs of dissolved nutrients, inputs of sediment from the adjacent landscape, and inputs of terrestrial organic matter (Gregory et al. 1991). All of these effects on physical and chemical factors can strongly influence the biotic characteristics of flowing waters. For these reasons, land-use practices in watersheds, especially in riparian zones, can significantly affect the integrity of stream ecosystems.

Data that address changes in land-use practices within drainage basin, watersheds, and riparian zones are not

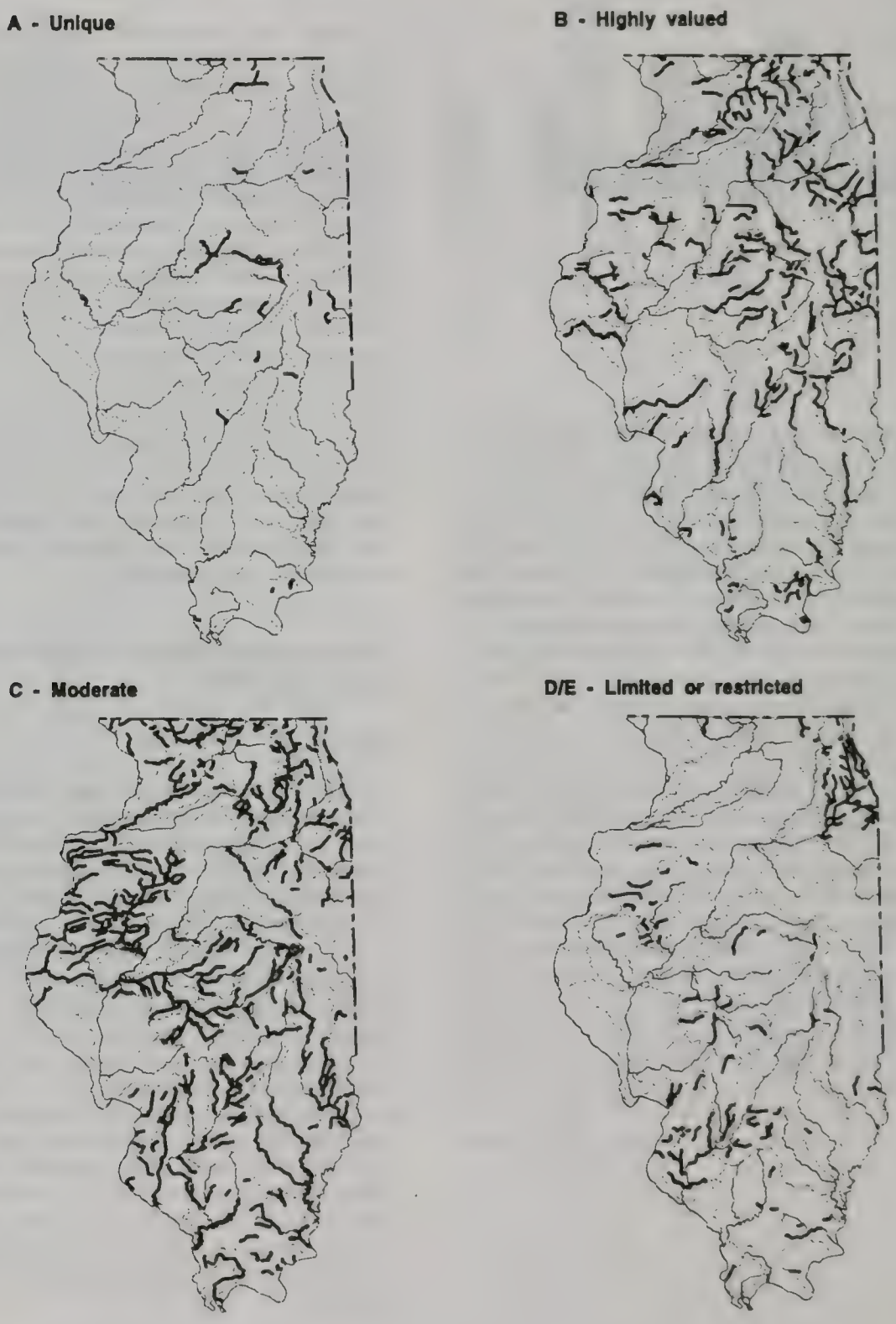


Figure 6. Biological characterization of Illinois streams.

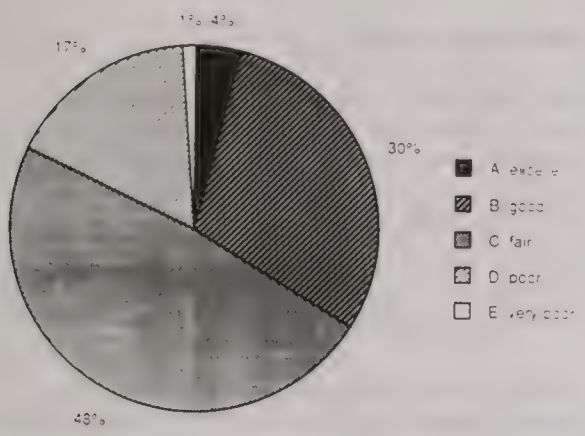


Figure 7. Percentage of Illinois stream miles surveyed that were rated by the Biological Stream Characterization in each classification.

currently available for the entire state. Extensive data are available for Champaign County, which we summarize below.

Five major drainage basins occur in Champaign County, with three of these (Kaskaskia, Embarras, Little Vermilion) originating within the county (Figure 9). For all basins combined, the amount of land in urban use increased markedly (37.4%) between 1958 and 1988, while the amount of land in agriculture and forest declined by 0.84% and 8.6%, respectively (Figure 10). These changes in land use were not uniform across basins. For example, forested land decreased by 80% in the Little Vermilion basin, with most of that land being converted to agricultural use (Osborne et al. 1991). The Embarras and Kaskaskia basins experienced 40% and 70% reductions, respectively, in forested land. However, in those systems, the land was converted largely to urban use (Osborne et al. 1991).

These basin-wide changes in land use do not accurately reflect changes that occurred in the riparian zone adjacent to streams. For example, the amount of urban land within 100 feet of a stream increased by 67.5% between 1958 and 1988 (Figure 10). Again, these changes in land use in the riparian area were not distributed uniformly among basins. For example, the amount of urban land within 100 feet of streams increased in the Embarras and Kaskaskia basins by 450% and 550%, respectively (Osborne et al. 1991). These basins and the Little Vermilion and Sangamon basins experienced appreciable losses (10–100%) of forested land adjacent to streams; in the Sangamon and Little Vermilion this land was largely converted to

Figure 8. Biologically significant Illinois streams.

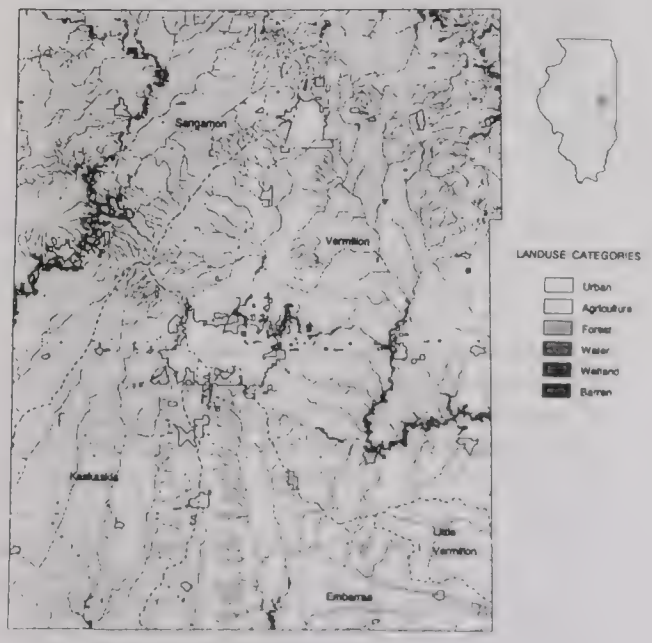


Figure 9. Champaign County land use.

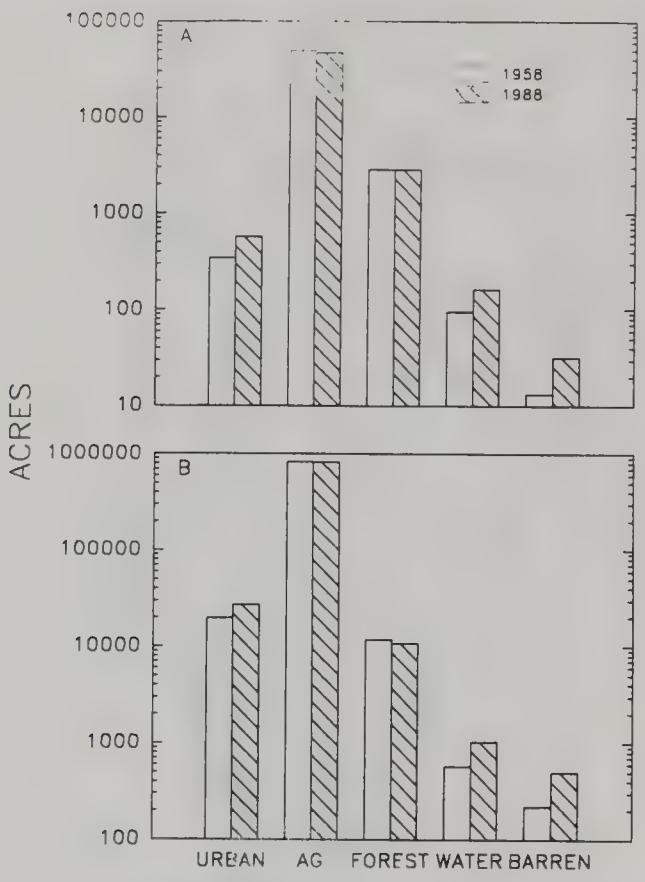


Figure 10. The amount of land in each of the five land-use categories in Champaign County: (A) within 100 feet of stream channels and (B) in the entire county. Land use was interpreted from 7.5-minute (1:24,000) (1988) or 15-minute (1:64,000) (1958) USGS topographic maps using GIS (ARC/INFO). Land-use/cover patterns within 100 feet of stream channels were determined using the ARC/INFO "buffer" facility.

agricultural use. These data indicate that a disproportionate amount of urbanization and, to a lesser extent, conversion of forested land to agricultural land has occurred in the riparian zone relative to other areas in the drainage basins. These trends in land use in the riparian zone are of particular concern because of the known value of forested riparian vegetation to midwestern streams (Karr and Schlosser 1978, Schlosser and Karr 1981, Osborne and Wiley 1988, Wiley et al. 1990) and because urbanization in the immediate vicinity of stream channels often has adverse effects on stream integrity (e.g., Karr and Dudley 1981, Osborne and Wiley 1988).

Dam Construction

Dam construction is one of the major physical alterations of Illinois' flowing waters. Almost every major river in Illinois has an impoundment along its course. There are nearly 1200 dams of all sizes in Illinois (Figure 11). The completion date was available for 110 dams (excluding those built on the Mississippi and Ohio rivers) with greater than 1000 acre-feet of normal water storage; these are discussed below.

There were two peaks in dam construction in this century (Figures 12 and 13). The 1930s saw large-scale changes in the nature of large rivers in Illinois. The Illinois and Mississippi rivers were converted from free-flowing rivers into a series of navigable pools by the construction of locks and dams (O'Brien et al. 1992). The second peak in dam construction occurred during the 1960s and 1970s. Recreation and, to a lesser extent, water supply were the reasons stated for the construction of these impoundments. The largest reservoirs in Illinois were completed during this time, including Carlyle (Kaskaskia River, 1967), Shelbyville (Kaskaskia River, 1970), and Rend (Big Muddy River, 1971). Flood control was the primary purpose recorded for these impoundments. High levels of dam construction continued during the 1980s. The average size of these impoundments, however, was much smaller than those built during the previous two decades (Figure 12). Coal mining and utility companies own 12 of the 18 dams constructed during the 1980s.

Physical, chemical, and biological alterations result from impounding a free-flowing stream. These changes occur both upstream and downstream of the dam and include alteration of temperature, flow regime, sediment transport, and chemical concentrations. Dams also present a barrier to migration and a loss of flowing-water habitat. Damming results in the creation of an artificial lake directly upstream from the dam and an altered lotic ecosystem in the receiving stream (Ward 1984). When multiple dams are placed along a waterway, such as on the Mississippi, Ohio, Illinois, and Rock rivers, the current and depth along the length of the river are altered, and the entire nature of the river is changed. A natural flowing stream, consisting of alternating riffles and pools, contains numerous distinctive habitats and, typically, high species diversity of fish and other aquatic organisms. In contrast, a reservoir on an impounded stream has comparatively low habitat and species diversity. Ward and Stanford (1979) and Baxter (1977) review some of the effects of dams and impoundments. Additionally, Ward and Stanford (1983) describe a conceptual framework (the

Figure 11. Illinois dams by mean storage capacity.

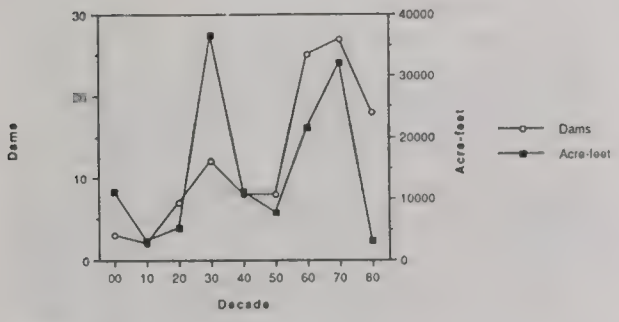


Figure 12. The number of dams constructed in Illinois in each decade between 1900 and 1990 and their mean normal storage. Only dams having greater than 1000 acre-feet of normal storage are included. This figure excludes 19 lock and dams constructed on the Mississippi and Ohio rivers. Source: Illinois Department of Transportation, Division of Water Resources.

Serial Discontinuity Concept) in which to view changes caused by an impoundment to a lotic ecosystem along a longitudinal profile.

A solitary factor can rarely be demonstrated to cause a change in the biota of a stream, but several authors have discussed the effects of dams on the biota of Illinois streams. Smith (1971) cited dams as one of the factors responsible for changes in fish populations in Illinois. He attributed the decimation of four native fish species to mainstream impoundments on the North Fork Vermillion and Embarras rivers, although he found the effects of dams on the fishes of the Mississippi, Illinois, Kaskaskia, and Rock rivers more difficult to assess. Suloway et al. (1981) discussed the effects of impoundment on the mussel fauna of the Kaskaskia River. Burks (1953) reflected on changes in the mayfly fauna near Rock Island in relation to the change of the Mississippi and Rock rivers from large, rapidly flowing rivers to sluggish water bodies.

Navigation/Barge Traffic

Barge traffic on the Illinois and Mississippi rivers has increased dramatically since 1950 although increases have leveled off in the past 10 years (Figure 14). Barge traffic and the activities associated with maintenance of the shipping channel may have a variety of deleterious effects on river ecosystems, few of which have been extensively examined. Propellers of tow boats are extremely large (up to 9 feet in diameter), and the outwash from these propellers can churn up the bottom of the river, moving and resuspending sediments into the water column and thereby altering the river bed. The impact of this type of disturbance on benthic fish and invertebrates is not clearly understood. The wake created by barges is also a potential source of environmental damage, increasing bank erosion and accelerating undercutting and exposure of the roots of trees in riparian forests along the banks of the rivers. Maintenance of the channel by dredging also potentially affects river ecosystems both through direct disturbance of benthic habitats when material is removed and also because the dredged material is deposited along the banks of the river, artificially building them up and separating riparian areas from the river.

Sport Fishing Pressure

Sport fishing in Illinois generates tremendous revenues from both residents and nonresidents alike. Statewide fishing pressure has increased dramatically since 1965, and at the current rate of increase Illinois can expect a 40% rise in total annual angling days (one angling day

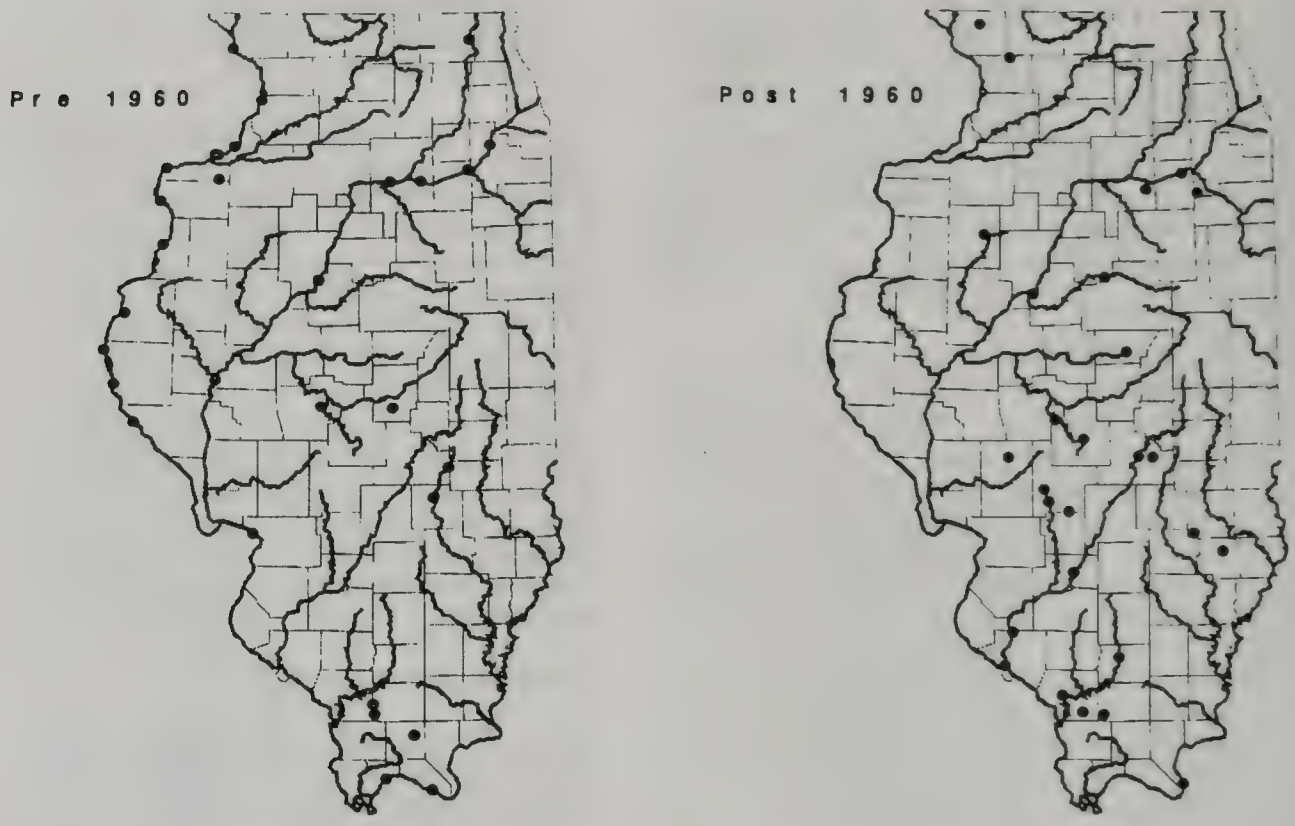


Figure 13. Illinois dams of 10,000 acre feet or greater storage by year of construction.

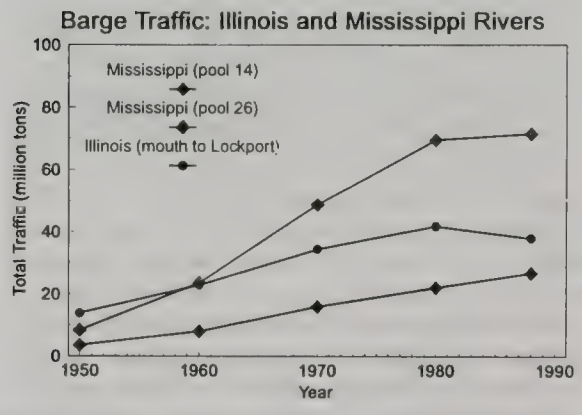


Figure 14. Volume of commercial traffic reported from sections of the upper Mississippi and Illinois rivers at 10-year intervals between 1950 and 1988. Pool 26 is above Alton and below the confluence of the Illinois and Mississippi rivers. Traffic reported from here is thus a composite of Illinois River traffic and traffic from the rest of the upper Mississippi River. Pool 14 is above Moline. Illinois River data is for the river below Lockport.

is one fisherman fishing all or any part of one day) by the year 2010 (Figure 15). Although approximately 70% of angling days are spent on public and private lakes, Illinois streams receive considerable fishing pressure annually (Baur 1991).

Overall, Illinois' streams have received approximately a 20% increase in total angling days from 1977 to 1989 (Figure 16). The Mississippi River has demonstrated the largest increase, receiving 52% more angling days in 1989 than it did in 1977. Other streams have received similar increases in fishing pressure (Figure 16). Fishing pressure in Illinois' small streams has fluctuated the most over the past decade and has actually experienced a 41% decrease in total angling days annually received since 1977 (Figure 16). However, the decline between 1986 and 1989 is probably a function of annual variation in water levels.

Although overall fishing pressure in our streams has varied dramatically, the hierarchy of the most popularly sought sport fish has remained relatively constant

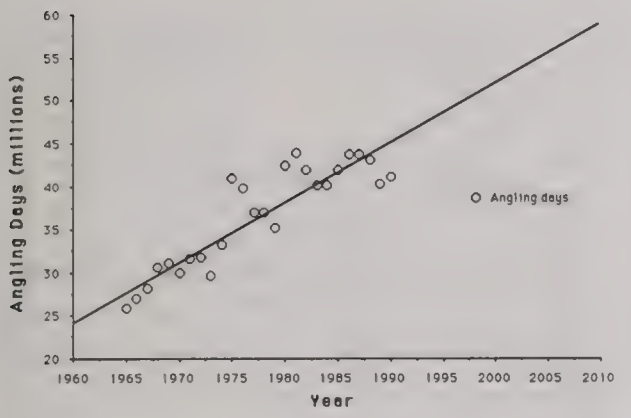


Figure 15. Number of days spent sport fishing in Illinois. More then 1.4 million anglers sport fished in Illinois during 1989, with only 4.2% of the anglers being from outside the state. Anglers averaged 28.3 fishing trips in Illinois during the year, with resident anglers averaging 29.0 trips and nonresident anglers averaging 11.9 trips. In 1990 anglers spent over 41 million days fishing in Illinois' lakes, ponds, and streams. At the current rate of increase, by the year 2010 the number of angling days is likely to increase by over 40% to approximately 57 million angling days per year (one angling day is one fisherman fishing all or any part of a day). The above projection was created from a regression analysis (r^2= .802) of angling day estimates from 1965 to 1990. Source: Office of Resource Management, Division of Fisheries, Illinois Department of Conservation, Springfield.

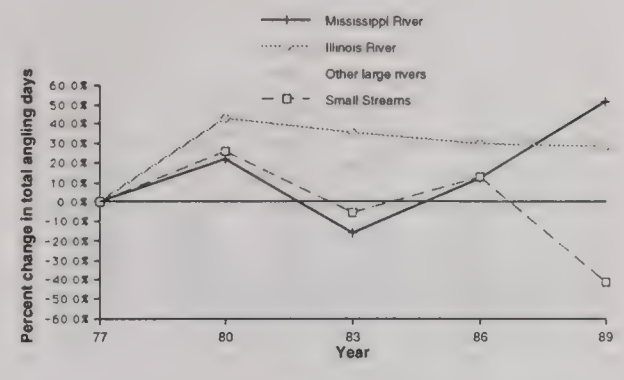


Figure 16. Percent change in sport fishing on Illinois rivers and streams, 1977–1989. Illinois' flowing waters have experienced dramatic increases in fishing pressure over the past 30 years. Between 1977 and 1989 the average number of angling days (one angling day = any one fisherman fishing all or any part of one day) spent by both resident and nonresident fishermen was over 11 million per year. The group of "other large rivers" receives approximately 4 million angling days per year, which is just under a million more angling days annually than received by the Mississippi River, averaging nearly 3.2 million. Small streams in Illinois and the Illinois River average approximately 2 million angling days annually. The zero percent line indicates the total number of angling days received by each group in 1977, and the following yearly estimates are increases or decreases in angling days relative to the 1977 estimate. Overall, there has been nearly a 21% increase in total angling days since 1977. The Mississippi River has received the largest increase with over 52% more angling days in 1989 than in 1977. Both the Illinois River and other large rivers have shown increases of nearly 30%. In contrast, small streams have experienced a 41% decrease in angling days annually. This drop, however, is most likely associated with a significant decrease in fishable surface area of small streams due to the 1988 drought, and therefore a large increase should be expected during the next survey period. Source: Office of Resource Management, Division of Fisheries, Illinois Department of Conservation, Springfield.

(Figure 17). Catfish, black bass, walleye and sauger, and crappie have remained the top four groups of sport fish sought after since 1977 (Figure 17). Of the four groups however, black bass have continually risen in popularity while preference for the others has remained fairly stable.

Fish Kills Attributable to Pollution

Streams are occasionally subject to disturbances so severe that they result in unusually high mortality of animals or plants in an area. Normally such disturbances result from natural causes (e.g., severe floods or droughts; see Hynes 1970), but they can also be induced by human activities. Fortunately, a common result (i.e., high mortality of fish) of such human perturbations to streams usually is quite obvious, and consequently, the events are often reported to the Illinois Environmental Protection Agency (IEPA) and/or the Illinois Department of Conservation (IDOC).

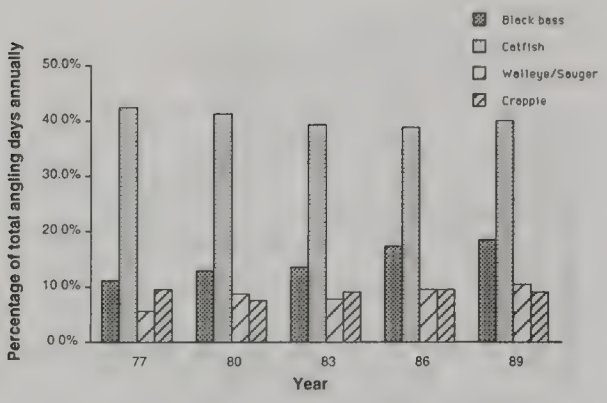


Figure 17. Hierarchy of the most sought sport fish species in Illinois, 1977–1989. This figure demonstrates that catfish species continually receive the highest fishing pressure, approximately 40% of the total number of angling days. Fishing pressure on black bass species has steadily increased since 1977. Wallye/sauger and crappie were the third or fourth most preferred species during this period. Although the popularity of these species does seem to be constant, it is important to realize that each year the absolute pressure received by any one of these species is rising.

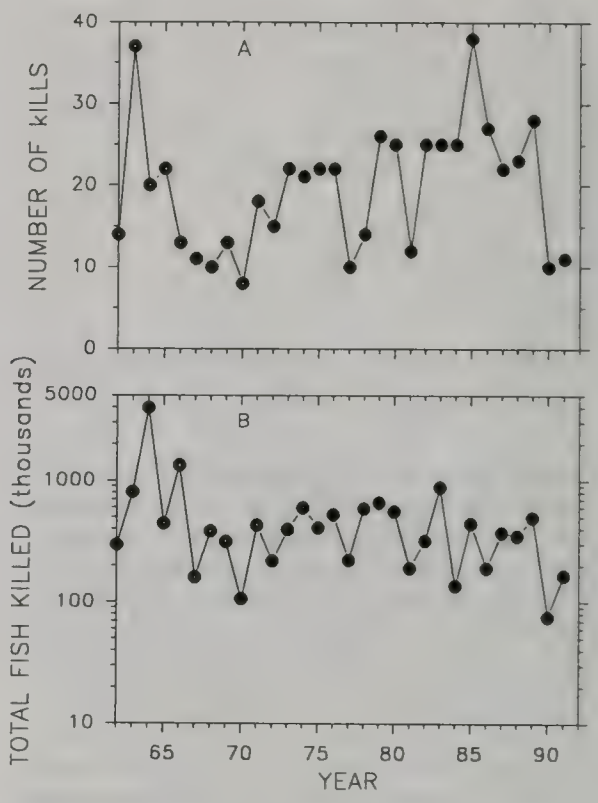


Figure 18. (A) The number of pollution-caused fish kills and (B) the estimated total number of fish killed in those events in Illinois streams between 1962 and 1991. Source: Illinois Department of Conservation annual reports.

The IDOC immediately investigates all reported fish kills and files a report including, when possible, an assessment of the probable cause of the high fish mortality. These records, then, serve as a rough index of one aspect of the relationship between Illinois and its flowing waters.

Between 1962 and 1991, an annual average of 19.6 fish kills that could be attributed to non-natural causes were reported from flowing waters in Illinois. These kills resulted on average in the loss of 532,000 fish annually. The data suggest that the annual number of fish kills has not declined over time; rather, there has been a trend toward an increased number of pollution-caused fish kills per year (Figure 18). The mean number of kills in the first 15 years of the 30-year period (17.9 ± 1.9 [SE]) is less than the mean number in the past 15 years (21.4 ± 2.1 [SE]). Since 1966, the number of fish kills reported per year has increased significantly (linear regression; $P < .05$) despite large year-to-year fluctuations. There has been no obvious trend in the estimated number of fish killed per year (Figure 18).

It is often difficult to ascertain the cause of a given pollution-caused fish kill, but two trends in the data seem apparent. The proportion of kills attributed to industrial pollution has declined steadily over the 30-year period and has leveled off at around 10% per year (Figure 19). At the same time, the proportion of kills attributed to agricultural pollution has increased steadily, at least through the mid-1980s (Figure 19). These trends are consistent with developments in water-quality standards and agricultural practices during the period. Stricter standards on the quality of water discharged into streams by industrial and municipal users began to be enforced during the 1960s, while the application of ammonia fertilizers, herbicides, and, to a lesser extent, pesticides on agricultural land has increased markedly in the past 30 years, especially during the 1960s and 1970s (see chapter on agricultural lands). Agricultural impacts (e.g., from runoff of ammonia), in contrast to the typical industrial and municipal situation, can rarely be associated with a single point of discharge into a stream. Such non-point sources of pollution remain a major threat to the integrity of Illinois' flowing waters.

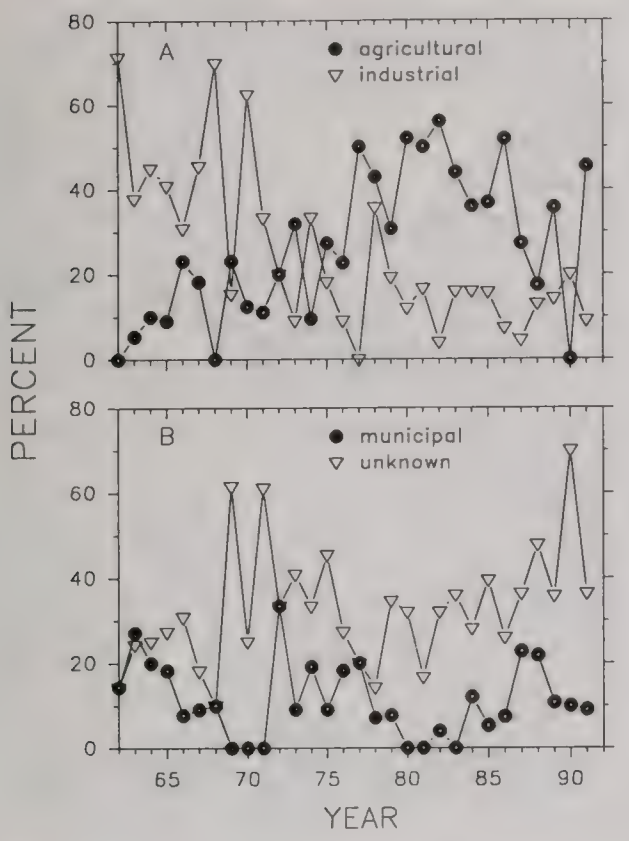


Figure 19. Percentage of all pollution-caused fish kills attributed to (A) agricultural and industrial pollution and (B) municipal pollution and unknown causes in Illinois streams between 1962 and 1991. Source: Illinois Department of Conservation.

Commercial Fish Harvest

A number of rivers in Illinois are exploited by commercial fisherman, but only four support fisheries of significant size and have been monitored more or less continuously by the Illinois Department of Conservation. These are the Mississippi, Illinois, Kaskaskia, and Wabash rivers. Data reported here for each of these rivers include both total catch (measured in pounds) and total value of catch reported as 1990 dollars. Value for catch was derived by multiplying reported data on fish caught by the average price per pound offered by fish buyers (obtained from phone surveys) for each year reported.

Catch is divided by species or group. These include buffalo (a combined catch of bigmouth buffalo [*Ictiobus cyprinellus*], smallmouth buffalo [*I. bubalus*], and black buffalo [*I. niger*]), carp (common carp [*Cyprinus carpio*]), catfish (a combined catch of channel catfish [*Ictalurus punctatus*], blue catfish [*I. furcatus*], and flathead catfish [*Pylodictis olivaris*]), drum (freshwater drum [*Aplodinotus grunniens*]), sturgeon (primarily shovelnose sturgeon [*Scaphirhynctius platorhynchus*]), and paddlefish (*Polyodon spathula*). The "others" category in the figures includes a variety of species taken in relatively small amounts, such as bullheads (combined catch of a number of *Ameiurus* species), white carp or carpsuckers (combined catch of quillback and other native carpsucker species [*Carpoides*]), gars (*Lepisosteus* spp.), and mooneye (combined catch of mooneye [*Hiodon tergisus*] and goldeye [*H. alosoides*]). Since the late 1970s, the non-native grass carp (*Ctenopharyngodon idella*) has also shown up in significant quantities in commercial catches, increasing from about 3000 pounds in 1975 to over 15,000 pounds in 1991. Catch data are summarized in Figures 20–25.

Caution should be exercised in deriving inferences about fish population dynamics from these data because no data are presented on fishing effort expended to obtain a particular level of catch. Total catch from all significant river fisheries ranges from 2.7 to 5.6 million pounds, generating an average yearly income of approximately $1.2 million. Across all river fisheries, two consistent trends were (1) the relative decrease in the importance of the carp fishery and (2) an increase in the importance of catfish. It is important to note that the two most valuable groups to the commercial fishery, the buffalo and the catfish groups, are native species.

Commercial Harvest of Freshwater Mussels

Pearl Button Industry. Freshwater mussels have been important economically at various times throughout history. John Boepple, a button maker from Germany, pioneered the use of freshwater mussels for buttons and began operating the first freshwater pearl button company in Muscatine, Iowa, in 1891 (O'Hara 1980). The button industry grew rapidly into a multimillion-dollar operation, and by 1908, it had a capital investment of over $2 million and an annual output of $6 million (Davidson 1924). Every town along the river, large or small, was in some way connected with the button industry (Coker 1919). In the early 1890s, when mussel fishing began at New Boston, Illinois, about 20 miles downstream from Muscatine, clammers harvested up to a ton a day, but by 1898, they had difficulty getting a ton in a week (Smith 1899). The mussel fishery and button industry rapidly expanded north and south on the Mississippi River and over to the Illinois River as mussel beds were depleted.

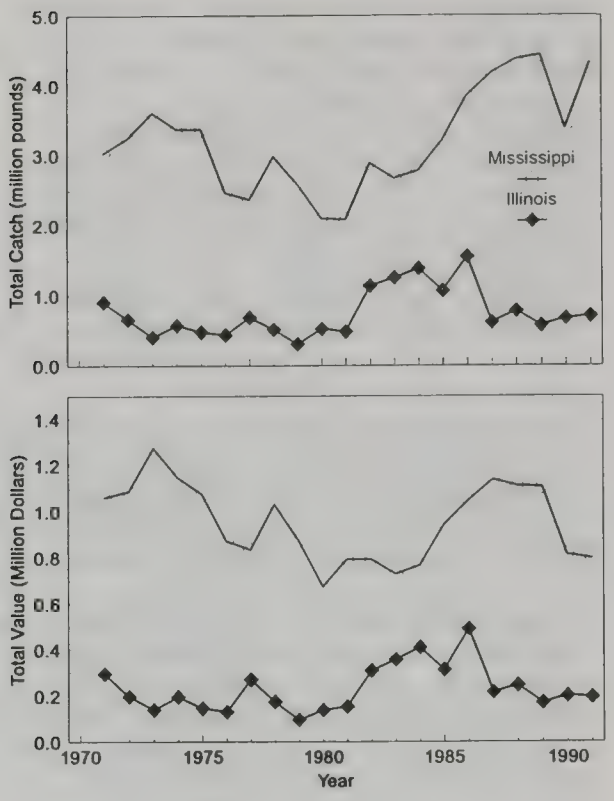


Figure 20. Total catch af all species (top) and 1990 dollar value of that catch (bottom) for the Illinois and Mississippi rivers from 1971 through 1991. The Mississippi River clearly supports the largest commercial fishery in the state, typically providing catches more than twice as large as those from the second largest fishery, the Illinois River. Mississippi River catches are variable, averaging around 3 million pounds per year. Catches appeared to exhibit a slow decline until 1980 (2.1 million pounds), after which they increased steadily through the 1980s, obtaining their highest peak in 1989 (4.4 million pounds). Illinois catches average about 650,000 pounds per year. From 1981 through 1986 catches remained relatively high, peaking at over 1.55 million pounds in 1986. Illinois River catches are still small compared to historical records indicating catches of over 17 million lb in 1908 and 5.6 million lb in 1950 (Starrett 1972). Mississippi catches have not varied as greatly from historical values, which ranged between approximately 3 and 4 million pounds from 1950 to 1970 (Sparks 1982). Value of catch for both rivers show less variation than total catch reflecting composition of catch and changing market prices. The Mississippi River provides a relatively consistent income of approximately $950,000 / year, whereas the Illinois generates about $227,000 / year.

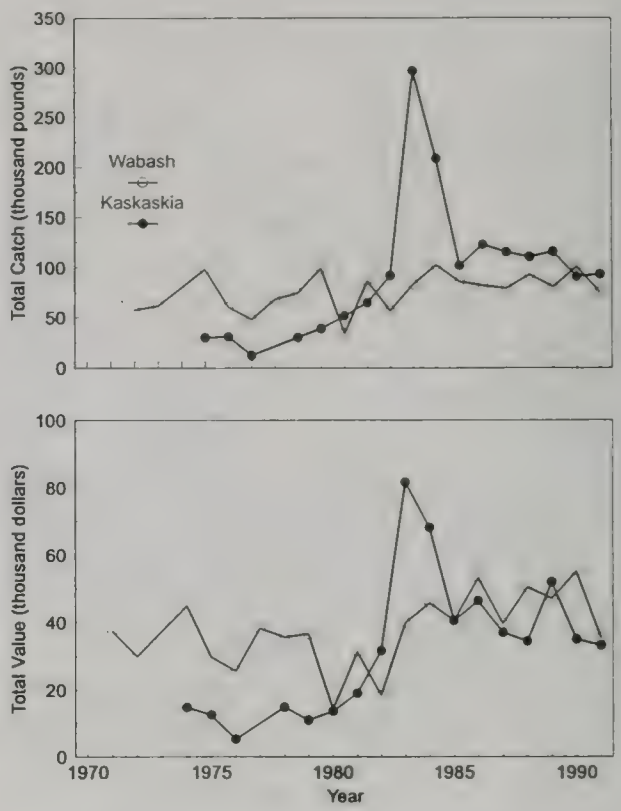


Figure 21. Total catch of all species (top) and 1990 dollar value of that catch (bottom) for the Wabash and Kaskaskia rivers from 1971 through 1991 (breaks represent years where no catch data was obtained). Kaskaskia River catches exhibited extreme variation, ranging from 12,000 to almost 300,000 lb. Catches increased dramatically after 1978, peaking in 1982 and 1983, then declining to approximately 110,000 lb / year afterward. Wabash River catches were much more consistent, varying from a low of 34,000 lb in 1980 to a high of 103,000 lb in 1984 with no clear upward or downward trends. Value of catch for both rivers tracks variation in catch reflecting composition of catch and changing market prices. The Kaskaskia River during 1982–1991 provided an average income of approximately $46,000 / year, whereas the Wabash has generated an average of $37,500 / year since 1971.

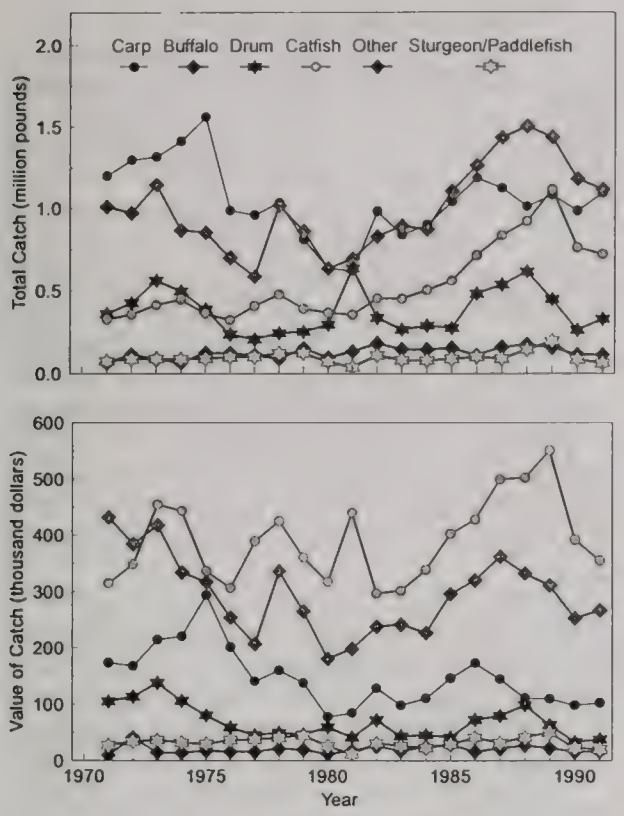


Figure 22. Catch (top) and 1990 dollar value of catch (bottom) for the dominant fish groups exploited by commercial fishermen in Mississippi River from 1971 through 1991. Carp and buffalo make up the bulk of the fishery, with carp being the predominant species taken before 1978 and buffalo predominating in the late 1980s. Catfish and drum are the next most important groups with catfish increasing steadily in importance since 1980. Catfish are also an important gamefish species in many rivers, and the potential for conflicts between sport and commercial fisheries is perhaps highest with this group. Sturgeon, paddlefish, and a variety of other species (carpsuckers, bullheads, mooneye, etc.) contribute small but consistent catches to the fishery. Although catfish are caught in smaller quantities than carp or buffalo, they consistently contribute the most value to the fishery, followed by buffalo and then carp. The value of carp and drum to the fishery appears to be declining, whereas the value of sturgeon, paddlefish, and other species appears to have remained relatively stable over the past 20 years.

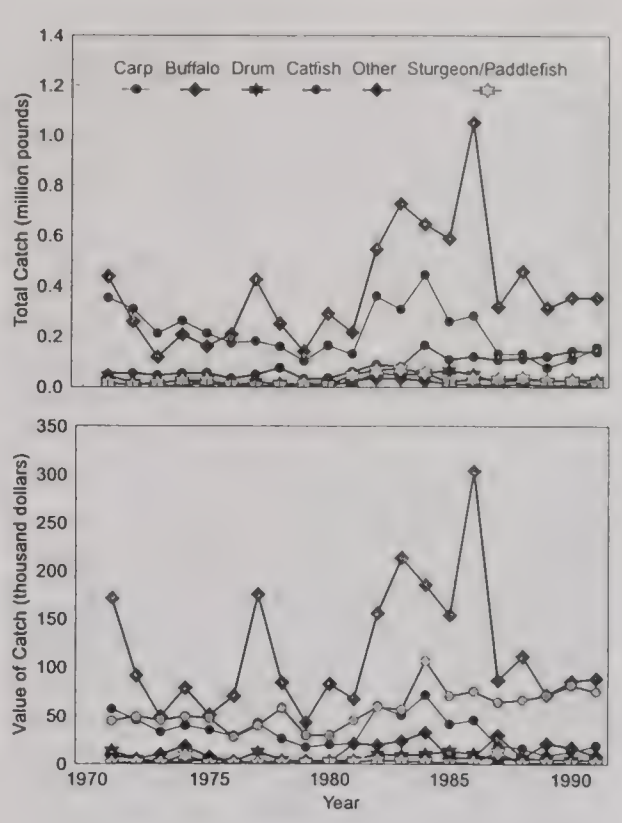


Figure 23. Catch (top) and 1990 dollar value of catch (bottom) for the dominant fish species exploited by commercial fishermen in Illinois River from 1971 through 1991. Buffalo is the predominant group caught in the Illinois River since the mid-1970s, and catches of this group increased dramatically in the 1980s declining after 1987. Carp were the second most abundant species in the fishery, although catfish (which have been steadily increasing in abundance) appear to be eclipsing carp in importance after 1988. Paddlefish and sturgeons do not represent a significant fishery in the Illinois River. Drum and other species contribute only very small amounts to the fishery. In terms of dollar value, buffalo is also the predominant group in the Illinois River. The value of this fishery closely tracks abundance in catch suggesting relatively stable prices for species over the past 20 years. Catfish are the next most valuable species, with a contribution approaching that of buffalo in some years. The value of the carp fishery approached that of catfish in the 1970s, but since 1982 the relative importance of this fishery appears to be diminishing. The remaining species combined contribute less than $50,000/year to the fishery.

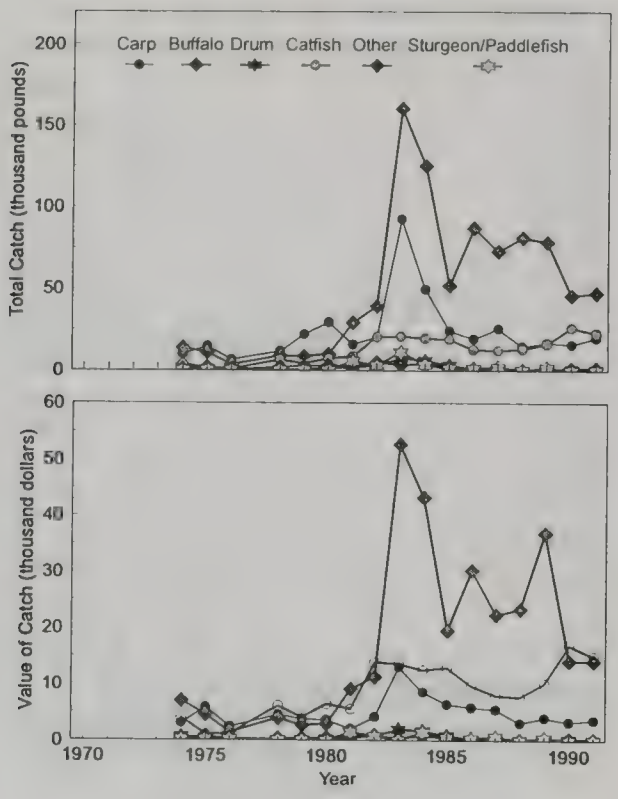


Figure 24. Catch (top) and 1990 dollar value of catch (bottom) for the dominant fish species exploited by commercial fishermen in the Kaskaskia River from 1974 through 1991 (data were not obtained from this system in 1977). Since 1981, buffalo has been the predominant fish group caught in the Kaskaskia River, which has yielded as much as 160,000 pounds of this species. As in the Illinois River, catches of carp have diminished while catches of catfish have remained relatively constant or shown upward trends. Other species including drum, paddlefish, etc., contribute relatively little to this fishery. Buffalo generated the most value in the fishery from 1983 to 1990, but value of catfish to the fishery has remained relatively constant while buffalo has been highly variable. Value of carp to the fishery appears to be decreasing steadily since 1983. Other fish species combined yield less than $3,000 / year to the fishery.

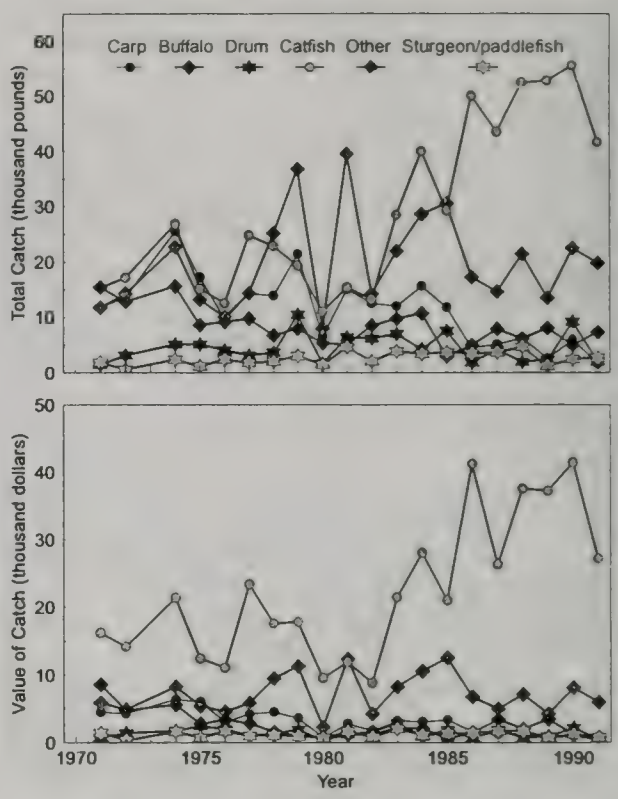


Figure 25. Catch (top) and 1990 dollar value of catch (bottom) for the dominant fish species exploited by commercial fishermen in the Wabash River from 1971 through 1991. The Wabash River fishery is a much more mixed fishery than that of the Kaskaskia or Illinois rivers. Although in some years more buffalo has been caught, the predominant fish caught in the Wabash has been catfish, and catches of this group have been increasing relatively steadily since 1979, achieving a high of almost 56,000 pounds in 1990. In contrast, carp catches have shown a downward trend. Catches of drum, paddlefish, and sturgeon remained small and relatively constant. Catch of other species (predominantly white carp and suckers) has exhibited a slight downward trend. Catfish clearly contribute the highest value to the Wabash fishery, generating over $41,000 in some years. The contribution of buffalo has been relatively constant around a mean of approximately $6300 / year. All other groups combined typically yield less than $5,000 / year

As pressure on the resource increased, the harvest exceeded the rate at which mussels could grow to harvestable size (Coker 1919). From 1912 to the 1930s, regulations including alternate closure areas, size limits, license fees, the reduction of wasteful practices at the factories, various anti-pollution measures, and gear restrictions were implemented. The alternate closure of sections of the Mississippi River in the Illinois-Iowa boundary waters temporarily restored mussel populations (Davidson 1924). However, the success of the alternate closure program was not long-lived because the beds were rapidly depleted after reopening. Depletion of the resource, the advent of plastics, and increasing pollution in the watershed led to a dramatic decline in the mussel fishery. By the 1930s, the pearl button era was coming to a close, and commercial clamming had virtually disappeared by the 1940s (Waters 1980).

The Cultured Pearl Industry. Kokichi Mikimoto of Japan discovered that freshwater mussel shells from the Mississippi River drainage produced the best nucleus for cultured pearls, and mussel harvest was revived in the 1960s to feed this growing industry. Millions of pounds of raw shells are exported to factories in Japan, where they are processed into spheres and then implanted into oysters as nuclei for cultured pearls. Harvest remained fairly stable from 1975 to 1985 and then rose rapidly in response to the high price being paid for shells due to the dwindling resource (Figure 26).

Regulations were weak during this revival in mussel harvest, and as recently as 1979, there were no restrictions on which species could be harvested in Illinois (Waters 1980). Meaningful and uniform regulations were not adopted until the mid-1980s, when concern peaked after a major mussel die-off in the Mississippi River from 1982 to 1985. Because of the intensified harvest and concern for endangered species, fish managers of the five Upper Mississippi River states met in 1985 to determine what actions should be taken to prevent further degradation of the mussel stocks. They recommended increasing the minimum size of harvestable mussels, reducing the length of the harvest season, and implementing harvest reporting requirements (Fritz 1990).

At present, 12 species can be legally harvested in Illinois, and the season runs from April 15 to August 31. Washboard (*Megalonaias nervosa*) and threeridge (*Amblema plicata*) are the two most important commercial species in Illinois and make up over 98% of the total harvest. A minimum size limit of 4 inches in height has been implemented for the washboard, which is the most highly prized species because of its large size and thick shell.

Comparing the data from 1987 to 1990, we see a tremendous increase in the number of mussels harvested from the Illinois and Mississippi rivers (Figures 26 and 27). In the Illinois River, live threeridge harvest more than doubled from just over 400,000 lb in 1987–1988 to over 900,000 lb in 1989–1990 (Figure 26). An increase of nearly 60% in live washboard harvest also occurred in the same time period (Figure 26). In the Mississippi River, the harvest of live threeridge has remained fairly constant at about 335,000 lb per year (Figure 26). Live washboard harvest has fluctuated from just over 1,000,000 lb in 1988 to 822,000 lb in 1990 (Figure 26).

What is most clear and potentially damaging to the long-term stability of the freshwater mussel resource is the astronomical increase in the number of miscellaneous species (i.e., species other than washboard and threeridge) harvested (Figure 27). Little if any data are available on sustainable yields for these species, and many populations could be drastically reduced or eliminated entirely if harvest continues at this rate.

Although total harvest in pounds for all species combined has risen steadily in the Illinois River over the past four years (Figure 27), it has remained somewhat constant in the Mississippi River, with a noticeable increase in 1989 (Figure 27). However, in both rivers, an increasing percentage of the total harvest is made up from either dead shells or the miscellaneous species category, and less consists of live washboards and threeridge, suggesting that demand is outstripping recruitment in these species. This increase in the demand for shells has caused the dollar value of the total harvest to rise steadily for the past four years in both rivers (Figure 27). The total value of the harvest in the Illinois River was approximately $130,000 in 1987 compared to over $1,000,000 in 1990. With very little data available on recruitment and sustainable yield for all mussel species harvested, the long-term stability of this resource is in serious question.

In Illinois, resident shellers and sheller's helpers need to purchase a license, and licenses are not available to nonresidents. In Illinois, resident and nonresident buyer's licenses are required. The buyer's report, like the sheller's report, varies among states and needs to become standardized. Because of differences in reporting requirements and the availability of reports, the three-year period on the Mississippi River from 1988 to 1990 is the only time span with harvest data available from the five Upper Mississippi River states: Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The total harvest from 1987 to 1990 was 17.8 million

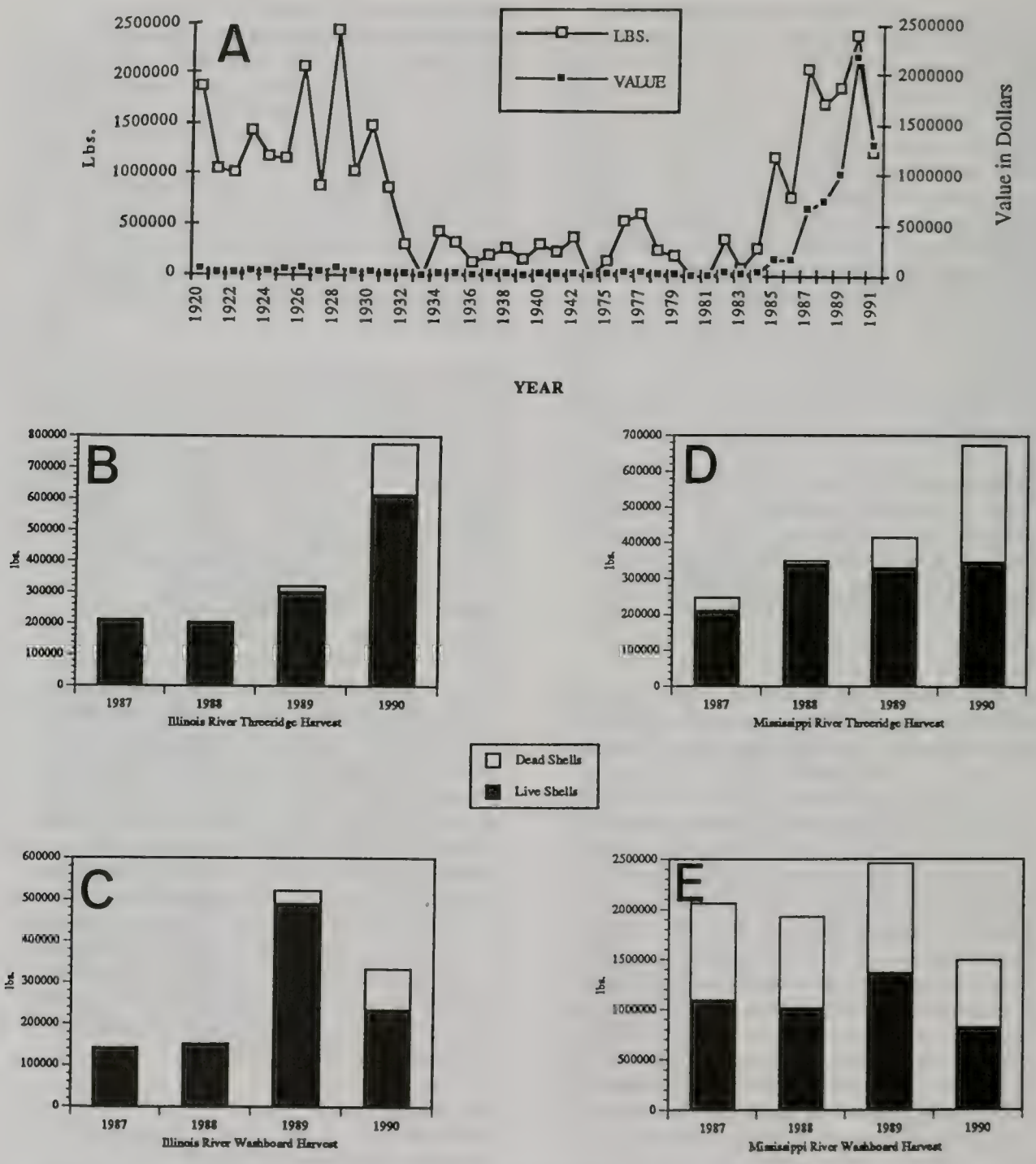


Figure 26. (A) Commercial harvest of mussels in the Mississippi River in terms of pounds harvested and dollar value. (B,D) Harvest of live and dead shell of threeridge in the Illinois and Mississippi rivers, respectively. (C,E) Harvest of live and dead shells of washboard in the Illinois and Mississippi Rivers, respectively.

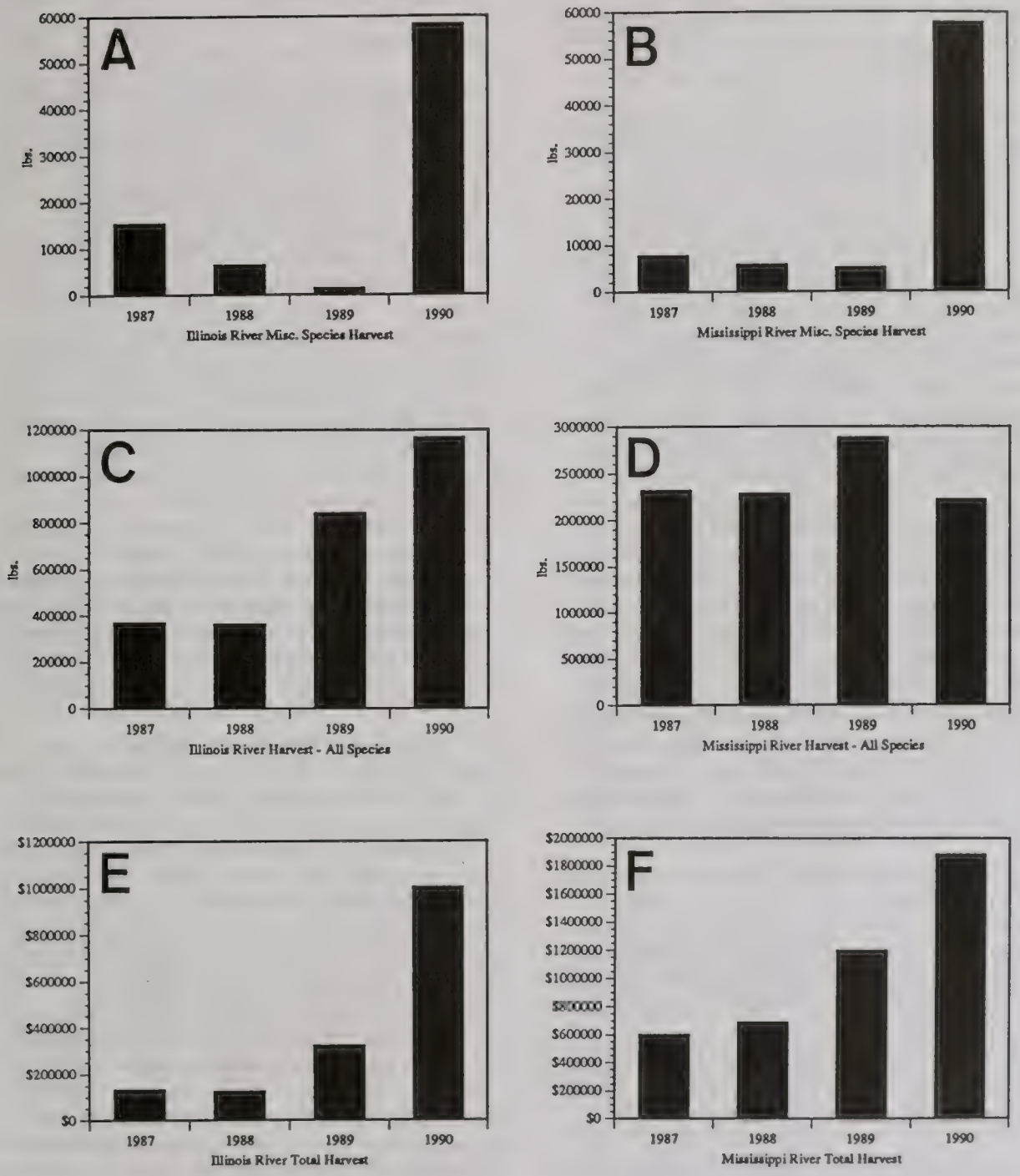


Figure 27. (A,B) Commercial harvest of miscellaneous mussel species in the Illinois and Mississippi rivers, respectively. (C,D) Total commercial harvest (in pounds) of all species in the Illinois and Mississippi rivers, respectively. (E,F) Dollar value of the total commercial harvest of mussels in the Illinois and Mississippi rivers, respectively.

pounds and was valued at $9.6 million. Illinois represents the largest percentage (42%) of the harvest, followed by Iowa (34%), Wisconsin (20%), Missouri (5%), and Minnesota (< 1%).

In 1989, the 3.7 million pounds of mussels harvested from the Illinois and Mississippi rivers had an approximate value of $1.5 million (Figure 27). Over 3.4 million pounds of mussels was harvested in 1990 and was valued at $2.9 million. A two- to threefold increase in the price paid for washboard (*Megalonaias nervosa*), an increasingly less common commercial species, caused this near doubling in value despite a 9% decrease in the number of mussels harvested (in pounds). As washboard availability decreased, threeridge harvest nearly doubled. It is doubtful that mussel populations are sustainable at this level of harvest, and trends should be analyzed carefully to determine whether further regulations are required.

The Future of Commercial Mussel Harvest. Projecting changes in the commercial mussel fishery over the next 10 years is difficult because of the large number of influencing variables, including market demand, cost of licenses, changes in minimum size limits, and changing habitat conditions. Potentially, the greatest threat to the native Illinois mussel fauna will be the impact caused by the introduction of the zebra mussel (*Dreissena polymorpha*) to the Mississippi River drainage in 1991. The freshwater mussel fauna of the Great Lakes has already suffered a devastating decline due to this exotic (Hunter and Bailey 1992).

Recommendations for future mussel management on the Upper Mississippi River include standardized sheller and buyer report forms, development of more uniform regulations, and continued implementation of the strategic mussel plan goals (Fritz 1990). Some of the high-priority objectives of the plan are to develop a solid base for funding and to continue research in areas such as life histories, status surveys, and the effect of commercial impacts and the zebra mussel on freshwater mussel populations.

Most of the data from this section on mussel harvest was excerpted from a paper by P. Thiel (U.S. Fish & Wildlife Service) and B. Fritz (Illinois Department of Conservation [retired]) presented at a symposium titled "Conservation and Management of Freshwater Mussels" held in St. Louis, Missouri, in October 1992. Their help is greatly acknowledged.

TRENDS IN BIOLOGICAL COMMUNITIES

Fish: Statewide

Native Fishes Reproducing in Illinois. At the turn of the century, 187 native fishes were reproducing in Illinois (Forbes and Richardson 1908). By 1979, eight native fishes had been extirpated (Table 2; Smith 1979). By 1993 (only 14 years later), another five species had disappeared from the state (Table 2), resulting in a total loss of 7% of the fauna present at the start of the century.

Several factors are responsible for the disappearance of native fishes (Smith 1971, Burr 1991, Page 1991). Principal among them are excessive siltation associated with the pervasive nature of agriculture in Illinois; the drainage of bottomland lakes that serve fishes as spawning areas, nurseries, and overwintering refuges; water pollution; stream desiccation that follows the lowering of the water table as groundwater is removed for agriculture and municipalities; competition and predation by introduced species; and dams that convert streams into standing water. These factors continue to affect Illinois streams, and another 28 species of fishes, listed as endangered or threatened species (Table 3), are in imminent danger of disappearing from Illinois.

Non-native Fishes Reproducing in Illinois. At the turn of the century, only one non-native species of fish, the carp, was reproducing in Illinois (Forbes and Richardson 1908). By 1979, eight non-native fishes were reproducing in Illinois (excluding four salmonids [chinook salmon, coho salmon, rainbow trout and brown trout] and one catfish [the white catfish] that were present in the state as the result of introductions but were not sustaining their own populations) (Smith 1979). By 1993, only 14 years later, eight more non-native fishes were established (Table 4), for a total of 16 species (not counting six introduced, but not self-sustaining, salmonids in Lake Michigan).

Five of the 16 species reached Illinois from Atlantic Slope drainages following construction of the Welland Canal (built in the 1820s to connect Lake Ontario with Lake Erie and allow ships to bypass Niagra Falls), three species have escaped from ponds and aquariums, four species were stocked in Illinois in an effort to improve fishing, and the remaining species were either accidentally introduced (rudd, silver carp, and possibly inland silverside) or introduced to help control aquatic vegetation in fish culture ponds (bighead carp). The five species that reached Illinois via the Welland Canal

Table 2. Extirpated species of native Illinois fishes.

Species lost by 1979
Ohio lamprey, *Ichthyomyzon bdellium*
Blackfin cisco, *Coregonus nigripinnis*
Muskellunge, *Esox masquinongy*
Rosefin shiner, *Lythrurus ardens*
Gilt darter, *Percina evides*
Saddleback darter, *Percina ouachitae*
Crystal darter, *Crystallaria asprella*
Spoonhead sculpin, *Cottus ricei*
Additional species lost by 1993
Alligator gar, *Atractosteus spatula*
Bigeye chub, *Hybopsis amblops*
Bluehead shiner, *Pteronotropis hubbsi*
Northern madtom, *Noturus stigmosus*
Harlequin darter, *Etheostoma histrio*

Table 3. Threatened and endangered Illinois fishes.

Endangered species
Northern brook lamprey, *Ichthyomyzon fossor*
Bigeye chub, *Hybopsis amblops*
Pallid shiner, *Hybopsis amnis*
Pugnose shiner, *Notropis anogenus*
Bluehead shiner, *Pteronotropis hubbsi*
Weed shiner, *Notropis texanus*
Cypress minnow, *Hybognathus hayi*
Greater redhorse, *Moxostoma valenciennesi*
Northern madtom, *Noturus stigmosus*
Western sand darter, *Etheostoma clarum*
Eastern sand darter, *Etheostoma pellucidum*
Bluebreast darter, *Etheostoma camurum*
Harlequin darter, *Etheostoma histrio*
Threatened species
Least brook lamprey, *Lampetra aepyptera*
Lake sturgeon, *Acipenser fulvescens*
Alligator gar, *Lepisosteus spatula*
Cisco, *Coregonus artedii*
Lake whitefish, *Coregonus clupeaformis*
Bigeye shiner, *Notropis boops*
Ironcolor shiner, *Notropis chalybaeus*
Blackchin shiner, *Notropis heterodon*
Blacknose shiner, *Notropis heterolepis*
River redhorse, *Moxostoma carinatum*
Longnose sucker, *Catostomus catostomus*
Banded killifish, *Fundulus diaphanus*
Spotted sunfish, *Lepomis miniatus*
Bantam sunfish, *Lepomis symmetricus*
Iowa darter, *Etheostoma exile*

are the sea lamprey, alewife, threespine stickleback, rainbow smelt, and white perch. The pond/aquarium escapees are the goldfish, Oriental weatherfish, and Rio Grande cichlid. Species introduced in efforts to improve fishing in Illinois are the carp, grass carp, threadfin shad, and striped bass.

Native Fishes with Expanding Illinois Distributions. Although many fishes have experienced range reductions in recent decades, a few species have expanded their ranges in Illinois in response to environmental changes (Table 5). The red shiner (*Cyprinella lutrensis*) has spread through much of central Illinois (Page and Smith 1970), north into Wisconsin, and up the Ohio River drainage of southern Illinois into Kentucky and the lower Wabash River (Burr 1991). The generally eastern movement of the species is thought to be related to environmental changes that favor species tolerant of wide fluctuations in pH, dissolved oxygen, and temperature (Matthews and Hill 1977). Other species (e.g., the suckermouth minnow, *Phenacobius mirabilis*, and bigmouth shiner, *Notropis dorsalis*), show a similar eastward-expanding pattern.

Several sport fishes and fishes used for bait, especially the fathead minnow (*Pimephales promelas*), have experienced range expansions as a result of efforts to improve sport fishing. The channel catfish (*Ictalurus punctatus*) and black crappie (*Pomoxis nigromaculatus*) recently have been found in Lake Michigan but were not known there when Smith (1979) surveyed the fishes of Illinois. The mosquitofish (*Gambusia affinis*) has been transplanted north of its native range in an effort to control mosquito populations.

In some instances range expansions are associated with range contractions in other species. The expansion in Illinois of the red shiner has been accompanied by a contraction in the range of two closely related native species, the spotfin shiner, *Cyprinella spiloptera*, and the blacktail shiner, *Cyprinella venusta* (Figure 28). With the loss of riparian vegetation, Illinois streams have become more turbid and variable in temperature, favoring the reproductive success of the environmentally tolerant red shiner over that of other species. As streams further degrade and populations of the red shiner increase, spotfin and blacktail shiners are unable to compete, and they disappear (Page and Smith 1970).

Table 4. Non-native fishes reproducing in Illinois.

Species established by 1979
- Sea lamprey, *Petromyzon marinus*
- Alewife, *Alosa pseudoharengus*
- Threadfin shad, *Dorosoma petenense*
- Rainbow smelt, *Osmerus mordax*
- Carp, *Cyprinus carpio*
- Goldfish, *Carassius auratus*
- Grass carp, *Ctenopharyngodon idella*
- Striped bass, *Morone saxatilis*

Additional species established by 1993
- Bighead carp, *Hypophthalmichthys nobilis*
- Silver carp, *Hypophthalmichthys molotrix*
- Rudd, *Scardinius erythrophthalmus*
- Oriental weatherfish, *Misgurnus aguillicaudatus*
- Inland silverside, *Menidia beryllina*
- Threespine stickleback, *Gasterosteus aculeatus*
- White perch, *Morone americana*
- Rio Grande cichlid, *Cichlosoma cyanoguttatum*

Table 5. Examples of native fishes with expanding Illinois ranges.

As a result of deliberate introductions as sport fishes
- Channel catfish, *Ictalurus punctatus*
- Redear sunfish, *Lepomis microlophus*
- Black crappie, *Pomoxis nigromaculatus*

As a result of deliberate introductions as forage for sport fishes
- Fathead minnow, *Pimephales promelas*

As a result of deliberate introductions for pest control
- Mosquitofish, *Gambusia affinis*

As a result of environmental changes
- Silverjaw minnow, *Ericymba buccata*
- Bigmouth shiner, *Notropis dorsalis*
- Red shiner, *Cyprinella lutrensis*
- Suckermouth minnow, *Phenacobius mirabilis*
- Banded darter, *Etheostoma zonale*

Fish: Champaign County

Four intensive surveys of stream fishes in Champaign County were completed at 30-year intervals beginning in the late 1890s (Figure 29). Cumulative fish species numbers by survey only varied between 55 and 61 (54 and 59 indigenous taxa) from a pool of 81 taxa that were recognized at the turn of the century. However, sampling efficiency varied greatly among techniques, which were less efficient in the earlier surveys. After correcting for species richness efficiency for each sample, mean numbers of indigenous species per sample declined greatly between 1928 and 1959 (Figure 29), a period during which row-crop agriculture was extended and intensified; also, chemical pollution of streams reached unprecedented levels by the late 1950s. A slight increase was suggested between 1959 and 1987. Paired sample analysis revealed that the biomass of various species (smallmouth bass, channel catfish, and grass pickerel) had increased significantly ($P<0.005$ after Bonferroni correction) during this period, an improvement that was probably due to an improvement in water quality since the dreadful conditions that existed in the 1950s and 1960s. However, physical habitat conditions have not improved during this period, during which riparian forest cover diminished (Osborne et al. 1991) and the physical effects of row-crop agriculture had not changed. Evidently, conditions for stream fish were much better during the first two surveys (Figure 29) even though extensive wetland drainage, tiling, and channelization had occurred before the 1890s.

Fish communities have also changed during the past 90+ years. In general, the percent occurrences of species have diminished (Figures 30 and 31), especially considering that the earlier two surveys used less efficient sampling methods. However, some species appeared to increase (Figure 32), including the introduced common carp. If these increases are not artifacts of increasing sampling efficiency, some interpretations are possible. Bluegill escape from impoundments and borrow pits, which have increased during the past 35 years. The creek chub and striped shiner are examples of minnow species tolerant of streams with low habitat quality, and the blackstripe topminnow is tolerant of low oxygen conditions, which frequently occur as a result of excess inorganic nutrients from agriculture and sewage treatment plants.

In conclusion, a strong trend in species richness was evident in which the mean number of fish species per sample descreased by a quarter between 1928 and 1959. This is attributed mainly to degradation in physical habitat and water quality due to changes in agricultural practices. No change in richness was noted since 1959, but the biomass of some piscivores increased. Percent occurrences of many species decreased during the 90-year period sampled, while tolerant species, such as creek chub, striped shiner, and the common carp (an exotic) increased.

Figure 28. Distribution of Cyprinella lutrensis (left) and Cyprinella spiloptera (right). Open circles denote 1908 locality records; solid circles denote locality records from 1950 to 1969. The shaded areas in the left figure indicate the major range expansions that occurred from 1908 to the present. The shaded area in the right figure indicates the range reduction that occurred from 1908 to the present.

Fish: Illinois River

Background. The Illinois River belongs to a world class of large river–floodplain ecosystems, where biological productivity (including fish yield) is enhanced by annual flood pulses that advance and retreat over the floodplain and temporarily expand backwaters and floodplain lakes (Junk et al. 1989, Sparks et al. 1990, Sparks 1992). The expanded aquatic habitats are utilized as feeding areas by migratory birds and as breeding areas and nurseries by fish and other aquatic life. The Illinois River today is the largest river (in terms of water flow) contained mostly within the state, and its fish populations reflect urban influences from the state's largest metropolitan area (the Chicago-Joliet area) as well as effects of land-use practices in the corn belt that runs across the middle of the state.

The river is divided into five reaches by navigation dams, including the Alton Dam (Dam 26) on the Upper Mississippi River, which influences the lower 80 miles of the Illinois River (Figure 33). These five reaches in turn fall into three major sections, defined by the natural physiography of the river and by the degree and nature of human alterations. The Dresden, Marseilles, and Starved Rock reaches together form the upper Illinois River, characterized by a geologically young channel with a relatively narrow floodplain between rocky bluffs. This section has been heavily influenced historically by effluents from the Chicago-Joliet area. The La Grange and Peoria reaches constitute the middle river. Here the river occupies a broad floodplain (2 to 5 miles wide) created by the ancestral Mississippi and Ohio rivers. Approximately half of the floodplain and the natural backwaters and lakes remain along this

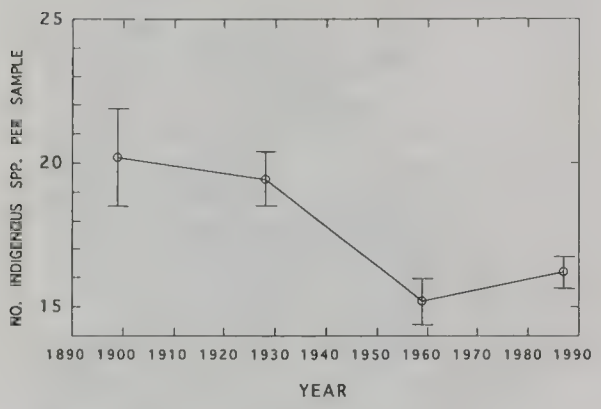


Figure 29. Mean numbers of indigenous fish species per sample after correction for gear efficiency for each of four surveys in Champaign County streams. The number of samples for each survey were as follows: 1898 (Forbes and Richardson), 46 samples (seine net); 1928 (Thompson and Hunt), 131 samples (seine net); 1959 (Larimore and Smith), 199 samples (electric and net seine); 1987 (Osborne and Bayley), 141 samples (mostly electric seine). Error bars are standard errors. Common carp and redear sunfish, which are exotic species, were not included. Eighty-one different fish taxa were collected during the 90-year period. This included eight "species pairs," such as orangethroat and rainbow darters, because confusion between certain species was evident due to the limited taxonomic knowledge at the turn of the century. These pairs were maintained in analyses in subsequent surveys in which both species were recognized, so that changing species richness was not a function of increasing taxonomic knowledge.

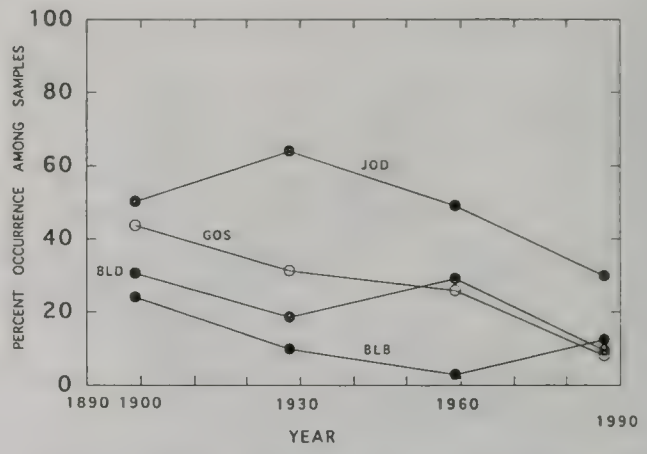


Figure 30. Percent occurrence among nonreplicated samples of selected fish species in Champaign County streams from four surveys (see references cited in Figure 29 legend; see also Bayley et al. 1989 and Bayley and Dowling 1990). Each species indicated a highly significant ($P<0.01$) difference among surveys (Bonferroni adjustments for multiple testing were applied) but not necessarily a trend with time. Different sampling effiencies affect probability of capture: solid symbols correspond to species in which efficiencies were 5–10 times lower using seine nets (which were used exclusively in the first two surveys) compared to the electric seine (which dominated the last two surveys); open symbols indicate similar efficiencies; shaded symbols indicate that seine net efficiencies were 2-5 times lower. Therefore, the darker the symbol, the greater percent occurrences were underestimated during the first two surveys. JOD = johnny darter (Etheostoma nigrum), GOS = golden shiner (Notemigonus crysoleucas), BLD = blackside darter (Percina maculata), BLD = black bullhead (Ameiurus melas).

section. In contrast, most of the floodplain and backwaters have been drained in the lower river (the Alton reach), and the river channel runs between two levees until it nears the confluence with the Mississippi River.

Stresses. Major historical stresses on the ecosystem include the following: (1) drainage of wetlands and channelization of tributaries in the drainage basin, mostly in the late 1800s but continuing to the present; (2) the diversion of Chicago sewage and industrial effluent from Lake Michigan to the Illinois River, via a system of waterways, starting in a major way in 1900; (3) leveeing and draining of half the floodplain in the 1920s, primarily for agriculture; (4) completion of the federal 9-foot navigation project in the 1930s; (5) intensification of agriculture in the 1950s, resulting from the shift from small grains, orchards, and pastures to row crops, and introduction of practices such as fall plowing and use of pesticides and chemical fertilizers; and (6) development of an industrial corridor (chemical manufacturing, petroleum refining, and storage of agricultural chemicals) in the 1950s along the upper river and its Des Plaines tributary in the vicinity of Joliet. Upland drainage and channelization of tributaries probably increased the rate of delivery of water, sediment, and pollutants to the main river. Diversion of sewage and Lake Michigan water raised mean water levels, caused the less flood-tolerant trees to die back

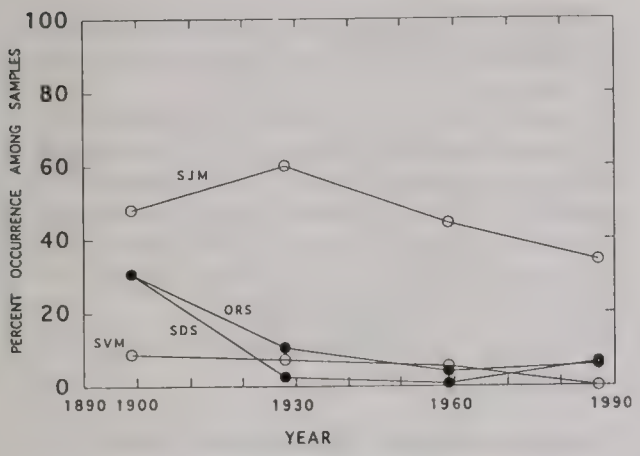


Figure 31. Percent occurrence among nonreplicated samples of selected fish species in Champaign County streams from four surveys (see references in legends of Figures 29 and 30) Each species indicated a highly significant (P<0.01) difference among surveys (except SVM which disappeared in the 1980s) (Bonferroni adjustments for multiple testing were applied) but not necessarily a trend with time. Different sampling effiencies affect probability of capture: solid symbols correspond to species in which efficiencies were 5-10 times lower using seine nets (which were used exclusively in the first two surveys) compared to the electric seine (which dominated the last two surveys); open symbols indicate similar efficiencies. Therefore, the darker the symbol, the greater percent occurrences were underestimated during the first two surveys. SJM = silverjaw minnow (Ericymba buccata), ORS = orangespotted sunfish (Lepomis humilis), SDS = spotted sucker (Minytrema melanops), SVM = silvery minnow (Hybognathus nuchalis).

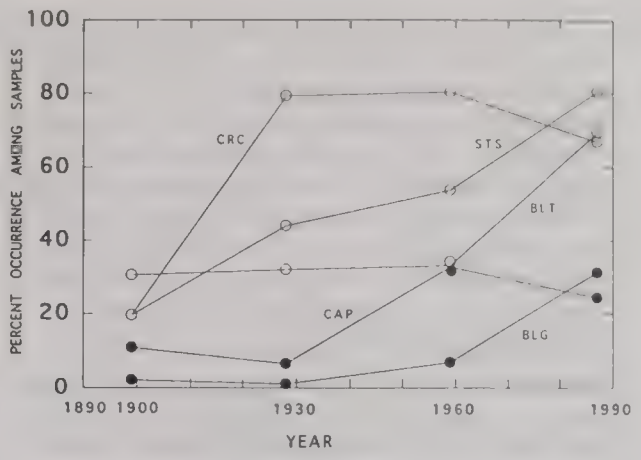


Figure 32. Percent occurrence among nonreplicated samples of selected fish species in Champaign County streams from four surveys (see references in legends of Figures 29 and 30) Each species indicated a highly significant (P<0.01) difference among surveys (Bonferroni adjustments for multiple testing were applied), but not necessarily a trend with time. Different sampling effiencies affect probability of capture: solid symbols correspond to species in which efficiencies were 5–10 times lower using seine nets (which were used exclusively in the first two surveys) compared to the electric seine (which dominated the last two surveys); open symbols indicate similar efficiencies. Therefore, the darker the symbol, the greater percent occurrences were underestimated during the first two surveys. CRC = creek chub (Semotilus atromaculatus), STS = striped shiner (Luxilus chrysocephalus), BLT = blackstripe topminnow (Fundulus notatus), CAP = common carp (Cyprinus carpio), BLG = bluegill (Lepomis macrochirus).

on the floodplain, and eventually degraded water and sediment quality (Mills et al. 1966). Drainage projects on the floodplain reduced fish and wildlife habitat and the capacity of the floodplain to convey or store flood water and concentrated sedimentation in the areas that remained open to the river. The navigation dams permanently inundated portions of the floodplain, so the soils do not dry and compact as they once did during low river stages in midsummer (Bayley 1991). Also, the wind fetch was greater on the expanded lakes and backwaters, so the heights of wind-driven waves increased and thereby increased resuspension of the unconsolidated sediments. The improved navigation system stimulated boat traffic, which also generated waves that resuspended sediments and contributed to bank erosion. Intensification of agriculture, coupled with stream channelization and removal of riparian vegetation, increased the rate at which water and sediments, and chemicals associated with them, were delivered to the river. The expansion of chemical handling and manufacturing on the upper river increased the risk of both chronic pollution and spills.

Response of Fish Populations to Recent Stresses. The Long-Term Electrofishing Survey. The fish populations of the Illinois River have been surveyed annually since 1957, except for a few years when no funding was available or sampling could not be

conducted because the river was in flood. The sampling is conducted at 28 permanent locations in the fall, using an electrofishing boat, when water levels are maintained at stable, low elevations by the navigation dams (Figure 33). Two stations are located in the Upper Mississippi River, near the confluence with the Illinois, for comparison (Figure 33). The entire data set has only recently been transcribed to computer disks and is still being verified against the original field data sheets. Although comparisons of the occurrence and general abundance of fishes can be made reliably across all the years (Tables 6–8), other comparisons are based on two years, 1963 and 1992, for which data are fully verified. We believe these two years are broadly representative of the condition of fish populations in the Illinois River at the beginning of the survey and in the most recent five years.

Species Composition and Abundance. Ninety-one species of fishes from 18 families, and five hybrids, have been collected during the electrofishing survey from 1957 to 1992. Over the entire period, just five species dominated the upper river, with the introduced goldfish and carp ranking first and second in abundance (Table 6, Figure 34). In recent years however, native species have returned to the upper river, and the electrofishing catch is dominated by native minnows, green sunfish, and gizzard shad (Figure 34). Carp now rank seventh in abundance (5.3% of the catch), and native fishes such as smallmouth and largemouth bass and bluegill sunfish constitute 3 to 4.6% of the catch (Figure 34). Carp and goldfish are more tolerant than most native species of the low oxygen levels and toxic materials associated with heavy pollution loads, and their populations often expand in the absence of pollution-intolerant predators (e.g., the basses) (Lubinski and Sparks 1981). The change to a more balanced fish community dominated by native species reflects improvements in water quality, as corroborated by a decline since 1975 in the toxicity attributable to ammonia, which is associated with sewage effluents (Figure 35). Another indication of improvement was the collection, independent of the electrofishing survey, of three state-endangered fishes in the upper river in the period 1987–1989: the pallid shiner, river redhorse, and greater redhorse (Page et al. 1992). In contrast to dominance by only five species in the upper river, 12 species were regularly abundant in the middle river and 10 in the lower river during most of the 35-year period covered by the electrofishing (Tables 7 and 8). The common carp ranked first in abundance in the middle and lower river in 1963 but was superseded by the bluegill by 1992 (Figures 36 and 37). In the lower river, largemouth bass ranked fourth in abundance, after gizzard shad and carp, and constituted 9% of the catch (Figures 36 and 37).

Some species that were once common are now virtually absent (Starrett 1971, Sparks 1977, Illinois Natural History Survey unpublished data). The yellow bass, northern pike, and black buffalo use flooded terrestrial or aquatic vegetation for spawning and may have declined because of alterations in the flood pulse or because of the loss of aquatic plants and general deterioration of shallow backwaters due to excessive sedimentation.

External Abnormalities. The incidence of external abnormalities (eroded fins, sores) in the fish declined markedly between 1963 and 1992, indicating a general improvement in water quality. However, abnormalities occur more frequently in fishes that contact bottom sediments (catfish, carp) than in fish that occupy the water column (bass, bluegill), indicating that there are pollutants or pathogens associated with the sediments (Figure 38). Also, the incidence of abnormalities increased in the upstream direction in both 1963 and 1992, implicating the Chicago-Joliet area as the source of whatever causes the abnormalities.

Body Condition. Fish biologists use a relative weight index (W_r) to indicate the general condition of fish. A value of 1 indicates that the weight of the fish in relation to its length is comparable to the top quartile of the fish that have been sampled in the same geographic region. A value below 1 indicates that the fish is underweight and may not be growing well. In general, fish in the Illinois River that feed in the water column, such as bluegill, appear to be in good body condition, whereas fish that feed on the bottom, such as carp, are in relatively poor condition (Table 9). Starrett (1971) related the poor condition of bottom-feeding fishes to the lack of invertebrates (fingernail clams, aquatic worms, and insects) on the bottom of the river. The paucity of bottom-dwelling invertebrates was in turn linked to the occurrence of toxic levels of ammonia in the sediments (Figure 39). Sediment toxicity increased upstream, implicating the Chicago area as the likely source.

Summary of Trends and Current Status. The relatively poor body condition of bottom-feeding fishes and the relatively high incidence of sores and eroded fins in fish that contact the bottom of the river indicate a lingering problem with sediments. A shift from dominance by goldfish and carp to a mixed community with substantial representation of native species, including sport fishes, indicates a general improvement

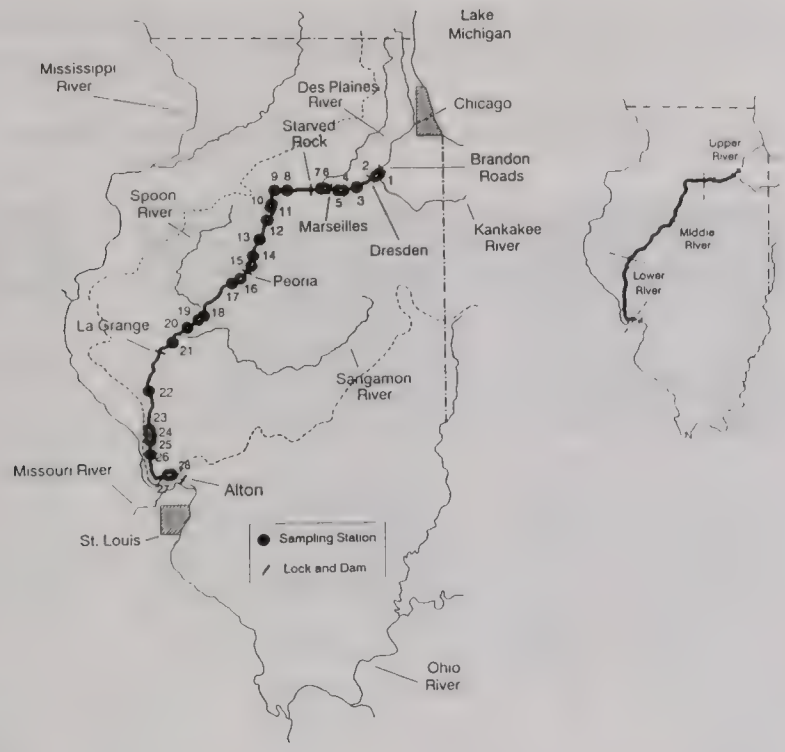
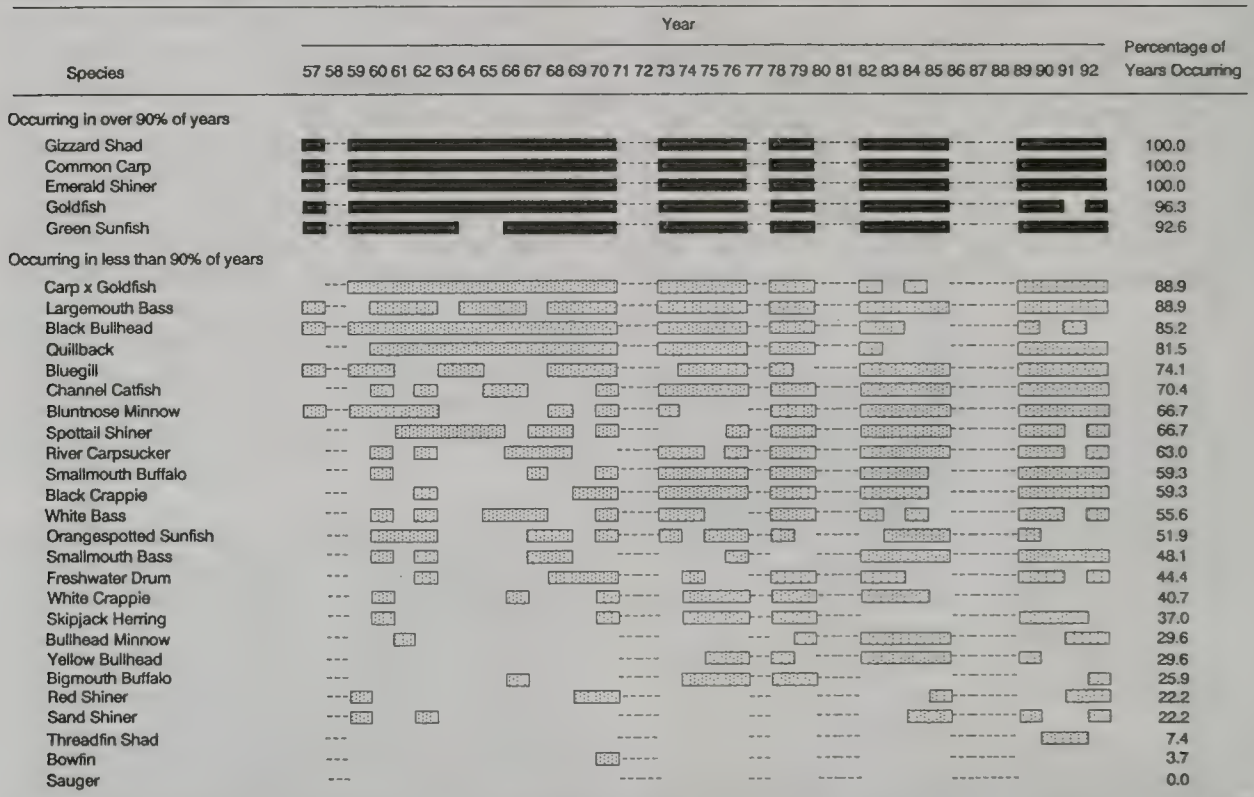


Figure 33. Locations of the 28 sampling stations along the Illinois Waterway and Mississippi River. Stations 27 and 28 are on the Mississippi River, just below the confluence with the Illinois River. (Data from stations 27 and 28 are not used in the following analyses because data have been gathered for only a few most recent years. Future analyses will, however, use data from these stations as representing control sites [i.e., being least affected by pollution from the Chicago-Joliet area], for comparison with Illinois Waterway data). Stations 1 and 2 are on the Des Plaines River. The rest of the stations are on the Illinois River. The Illinois Waterway is divided into reaches defined by navigation dams. The Alton Dam on the Mississippi River also maintains water depths for navigation on the lower 80 miles of the Illinois River. In upstream order, the other dams and the reaches they control are as follows: La Grange, Peoria, Starved Rock, Marseilles, and Dresden. The reaches can be grouped based upon the amount of aquatic habitat (side channels, backwaters, and floodplain lakes) available per unit length of river as follows (data from Gilbertson and Kelly 1981): The upper river flows through a much narrower valley than the other sections and has the least amount of aquatic habitat, due to a different geologic history than the rest of the river. The middle river has the most aquatic habitat, while the lower river has had most of its floodplain aquatic habitat converted to agriculture, and is now more similar to the upper river in terms of available floodplain habitat. The gradient in the upper river is 1 to 2 feet per mile (200 to 400 cm/km), while the gradient in the middle and lower sections is only 0.1 to 0.2 foot per mile (20 to 40 cm/km.).

in the water quality of the Illinois River. In addition to the intrinisic value of conserving and restoring native aquatic species in the Illinois River, there are recreational and economic benefits as well. As a result of improvements in water quality and fish populations, the river currently provides 2 million angling-days per year, valued at $40 million annually, based on 1989 figures (Conlin 1991). Sauger populations in the upper river and bass populations in the middle and lower river now support nationally ranked tournaments that are important to local and regional economies. Peoria, for example, will host a 1993 Bassmaster Superstars tournament, with the option to host it again in 1994 and 1995. Marketing studies indicate the Superstars tournament brings $6–8 million to the host city in expenditures by competing anglers, spectators, and news media, and the publicity boosts interest in outdoor recreation at the host site even after the

Table 6. Presence (dark or stippled) or absence (blank) in the upper Illinois Waterway of commonly occurring fish species (species accounting for 95% of all individuals collected), 1975-1992.*



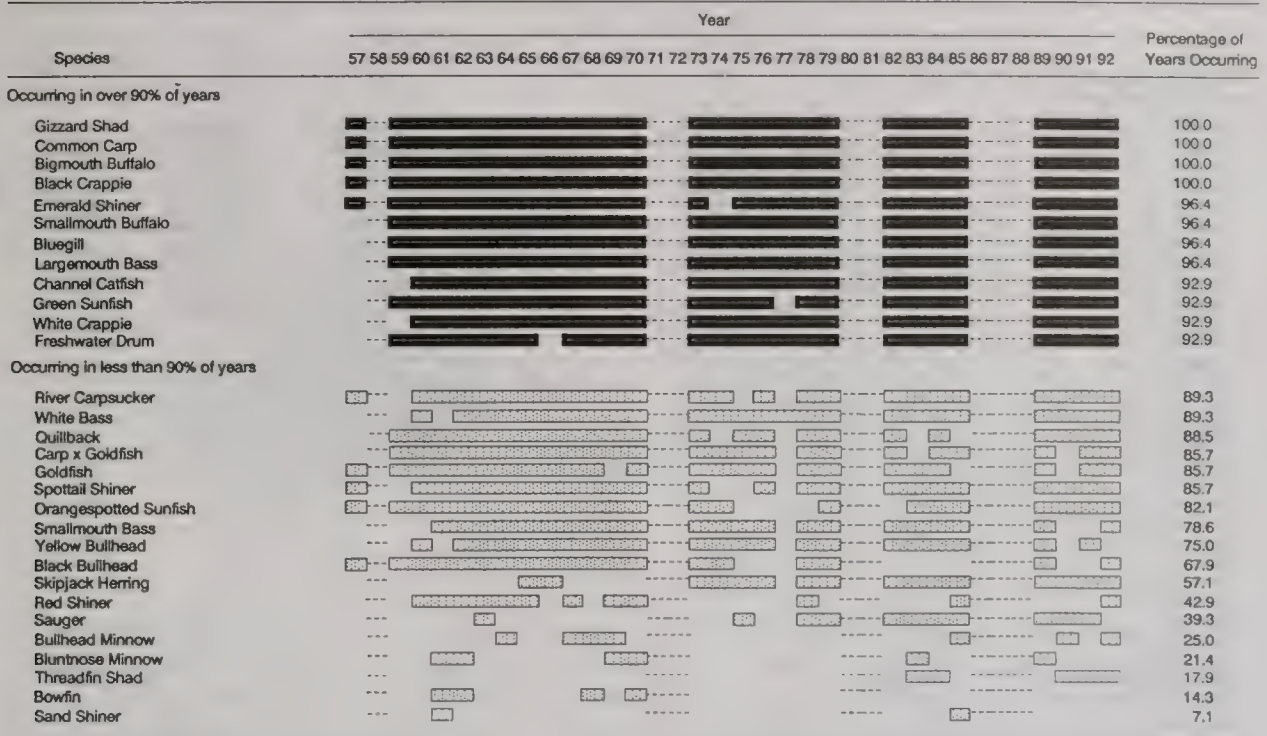
* Black bars indicate species that occurred in over 90% of years. Stippled bars indicate species that occurred in less than 90% of years. Dashed lines indicate years when electrofishing was not conducted. Five species were consistently collected in 90% or more of all years, two of which, goldfish and carp, are pollution-tolerant, non-native species. Carp x goldfish hybrids were also collected in most years, a fish usually associated with polluted conditions. Centrarchid species, usually identified as pollution-sensitive fishes (e.g., largemouth and smallmouth bass, bluegill, black crappie) have been collected more consistently since 1982 than in the earlier years of the survey, an indication of improved water quality.

tournament (Conlin 1991; Jack Ehresman, Peoria Journal Star, personal communication).

Prognosis. Despite the change to a better balanced fish community in the Illinois River over the past 30 years, with native species gaining in dominance over introduced species, problems remain. In addition to sediment quality, these include introduction of additional non-native species, chemical contamination of fish, lack of critical information on fish and fisheries, general habitat deterioration and diminishment of the flood-pulse, and lack of a concept of what a river-floodplain ecosystem is, as a basis and guide for management and restoration.

Non-native Species. It is ironic that improvements in waste treatment in the Chicago area lower the pollution barrier that once kept non-native species introduced to the Great Lakes from invading the entire Mississippi drainage via the artificial link to the Illinois River. The latest introduction is the European zebra mussel, first reported in the Illinois River in June 1991, now found throughout the Illinois River and at scattered locations in the Upper Mississippi, Ohio, and Tennessee rivers (Sparks and Marsden 1991, Sparks 1991). This mussel is capable of reaching densities of thousands per square yard and could have indirect effects on fish populations by altering the base of the food chain and smothering native mussel beds that some fishes use as spawning substrates. The white perch (originally from the Atlantic coast) has invaded the Illinois River from the Great Lakes within the past two years and the European river ruffe (a small fish) is likely to follow soon. Invaders from the Mississippi include the Asiatic clam,

Table 7. Presence (dark or stippled) or absence (blank) in the middle Illinois Waterway of commonly occurring fish species (species accounting for 95% of all individuals collected), 1975–1992.*



* Black bars indicate species that occurred in over 90% of years. Stippled bars indicate species that occurred in less than 90% of years. Dashed lines indicate years when electrofishing was not conducted. Twelve species were consistently collected in 90% or more of all years, which includes a larger number of pollution-sensitive Centrarchid species (e.g., black and white crappie, largemouth bass, bluegill) than on the upper waterway (Table 6). The consistent occurrence of bigmouth bufffalo, a native fish that requires backwaters for spawning, compared with the upper waterway (Table 6), is related to the much greater amount of backwater habitat along the middle river.

Corbicula, which is likely to be followed by the grass carp and the bighead carp, also from Asia. The Asiatic clam arrived in 1971.

Chemical Contamination of Fish. While fish community changes provide indirect evidence that water quality has improved, sediments in some areas, especially on the upper river, contain elevated levels of toxic substances such as heavy metals and synthetic organic chemicals (Essig 1991), which can accumulate in fish tissues from direct contact with sediments or be magnified in concentration through the food chain from sediments to benthic invertebrates to invertebrate-feeding fishes. Fish consumption advisories are in effect for the upper river and the middle river to the Peoria Dam for bottom-feeding fishes such as freshwater drum, channel catfish, smallmouth buffalo, and carp over 15 inches (38 cm) (Illinois Department of Conservation 1993). The persistent nature of the toxicants makes this problem particularly intractable.

Lack of Critical Information on Fish and Fisheries. As encouraging as the redevelopment of the Illinois River sport fishery is, there is too little information available to manage and regulate this fishery. No creel surveys have been done to determine how many fish are being harvested. The effects of moving several hundred of the largest bass in the La Grange reach of the river upstream through the lock and dam into the Peoria reach is not known, yet this is what happens with each major bass fishing tournament held at Peoria, because most of the fish are caught in the La Grange reach and released, after weighing, in the Peoria reach. The nationally ranked tournaments and local fishing may be based on just a few year-classes of bass and sauger, and the number of large fish may dwindle soon, unless the

Table 8. Presence (dark or stippled) or absence (blank) in the lower Illinois Waterway of commonly occurring fish species (species accounting for 95% of all individuals collected), 1975–1992.*

Species	Year: 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92	Percentage of Years Occurring
Occurring in over 90% of years		
Gizzard Shad		100.0
Common Carp		100.0
Channel Catfish		100.0
White Bass		100.0
Black Crappie		100.0
Bluegill		95.5
Largemouth Bass		95.5
Freshwater Drum		95.5
Emerald Shiner		90.9
White Crappie		90.9
Occurring in less than 90% of years		
Bigmouth Buffalo		86.4
Green Sunfish		72.7
River Carpsucker		68.2
Smallmouth Buffalo		59.1
Quillback		40.9
Skipjack Herring		36.4
Sauger		36.4
Orangespotted Sunfish		31.8
Threadfin Shad		18.2
Smallmouth Bass		18.2
Bowfin		13.6
Yellow Bullhead		13.6
Carp x Goldfish		9.1
Red Shiner		9.1
Goldfish		4.5
Spottail Shiner		4.5
Black Bullhead		4.5
Bluntnose Minnow		0.0
Bullhead Minnow		0.0
Sand Shiner		0.0

* Black bars indicate species that occurred over 90% of years. Stippled bars indicate species that occurred in less than 90% of the years. Dashed lines indicate years when electrofishing was not conducted. Ten species were consistently collected in 90% or more of all years, which includes pollution-sensitive centrarchid species (e.g., largemouth bass, bluegill, black and white crappie) as well as white bass. In sharp contrast to the other sections of the river, goldfish and carp x goldfish hybrids, non-native pollution-tolerant fishes, were collected in few years, an indication that the lower waterway suffers less from urban and industrial wastes. Small minnow species (e.g., red shiner, sand shiner, spottail shiner, bluntnose and bullhead minnows) were less consistently collected from the lower waterway than the upstream sections, which could reflect differences in habitat conditions (e.g., fewer aquatic plants for use as cover than in the upper waterway, fewer backwaters than in the middle section, the leveeing and draining of the floodplain) or other factors as yet undetermined.

critical spawning and wintering habitats and conditions can be identified and preserved. Also, the population of large fish may be quite small, but the fish are concentrated and easily caught during low water levels because they are forced out of backwaters made shallow by excessive sedimentation. If this is the case, then length restrictions and catch-and-release regulations would help maintain the supply of large fish, and restoration of backwaters would help increase the supply.

Even less is known about the nongame species and endangered species. Therefore, it is imperative that research on these species be initiated and conducted simultaneously with restoration, to the extent possible, of the natural habitats and floodpulse that maintained these species prior to disturbance. More will be said about this approach below.

Habitat Deterioration. Although the black basses, sunfishes, and crappies (Family Centrarchidae) are responding favorably to improvements in water quality, particularly in the upper river, further improvements in the middle river and lower river may be limited by continuing heavy sediment loads and deterioration of backwater habitats. Suspended sediment concentrations have decreased over the past 15 to 20 years (late 1970s to late 1980s) in the Upper Mississippi River but have not changed significantly in the Illinois River (Gaugush 1992, 1993). Suspended sediment not only reduces the visibility sight predators need to find their food (and fishermen's lures), it reduces the amount of food as

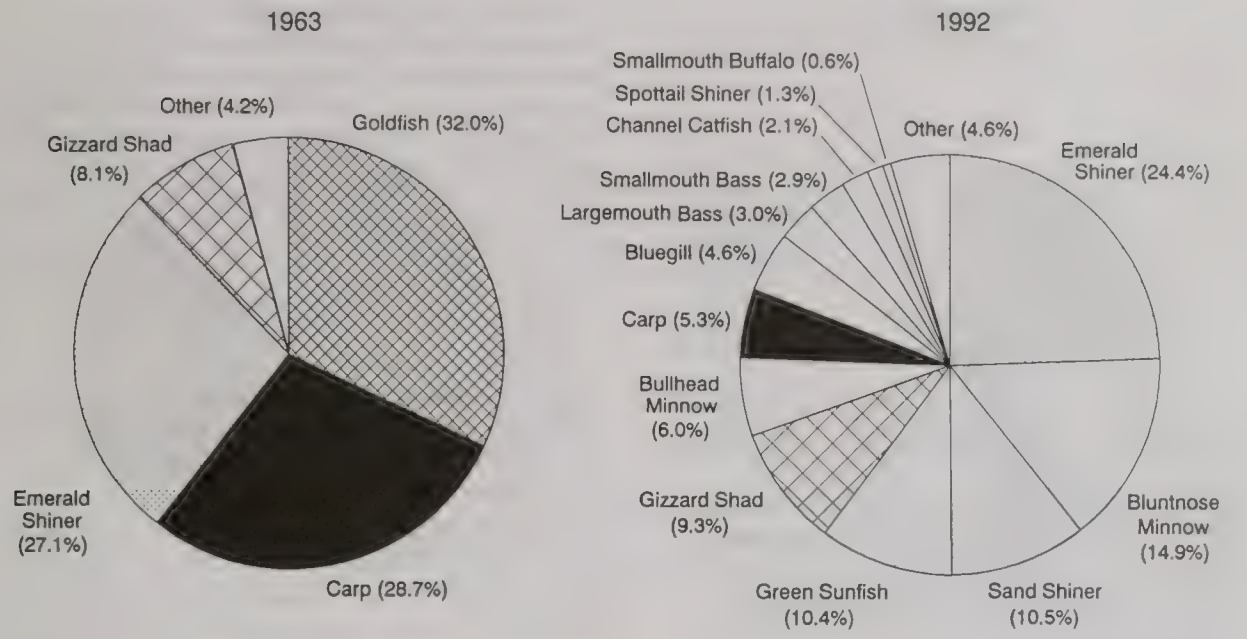


Figure 34. Percentages of catches by species for the upper Illinois Waterway, for 1963 and 1992, based on number of individuals collected per hour of electrofishing. In 1963, goldfish, a non-native species, accounted for almost one-third of all fish collected per hour, followed by carp (also a non-native), emerald shiner, and gizzard shad. In 1963, these four pollution-tolerant species accounted for 95.8% of all individuals collected per hour. In contrast, in 1992, 13 species accounted for approximately 95.4% of all fish collected per hour, and goldfish were collected in insignificant numbers, while carp were reduced to a minor component. In 1992, pollution-sensitive centrarchid species (e.g., largemouth and smallmouth bass, bluegill) made up substantial portions of catches; in addition, minnow species (e.g., emerald shiner, sand shiner, bluntnose minnow), important as a forage base for piscivorous fishes, showed a higher diversity than in 1963. Species are arranged in descending order of relative abundance in a clockwise direction and are labeled separately until approximately 95% of the pie is filled.

well (Vinyard and O'Brien 1976, Buck 1956). The centrarchids also have complex reproductive and social behaviors that depend on visual cues, and their eggs and larvae are susceptible to smothering with sediment or predation if the guardian male cannot see and defend them. The recovery of many other species (e.g., yellow bass, northern pike, black buffalo, and several species of minnows and darters) likewise is limited by excessive turbidity, unstable bottoms, and absence of aquatic vegetation.

Lack of an Organizing Concept for Management and Restoration. Unfortunately, the current remedies for habitat deterioration may be ineffective and may create other problems for aquatic organisms because the remedies are not founded on a holistic understanding of the river-floodplain ecosystem. There currently are nine multimillion-dollar habitat rehabilitation and enhancement projects in various stages of design or construction on the Illinois River, all part of the Environmental Management Program for the Upper Mississippi River and Illinois River conducted by the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and the five states of the Upper Mississippi River Basin, including Illinois. There are many aspects to these large, complex projects, but most involve keeping sediment-laden river water out of floodplain impoundments to the maximum extent possible. These techniques are expected to encourage the growth of aquatic plants in the clear water behind levees or moist-soil plants in impoundments that are drawn down to expose mudflats. While these measures will probably benefit ducks and geese, and fish that are stocked in the impoundments, the ecosystem functions of flood storage and conveyance and use by migratory fishes will not be restored. There are considerable economic

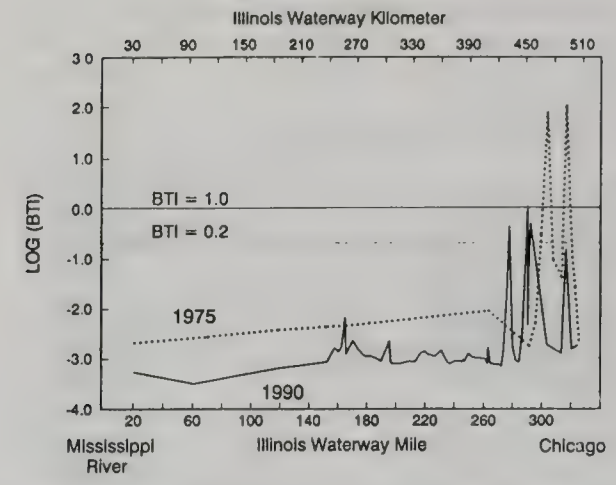


Figure 35. Mean bluegill toxicity index (BTI) calculated for 1975 (16 stations) and 1990 (66 stations). The BTI was developed by Lubinski et al. (1974) and can be used to compare the relative toxicities of different substances to a reference organism, the bluegill. Calculation of the BTI requires values for pH, water temperature, dissolved oxygen concentration, fish weight, and concentration of the toxicant (data from Illinois Environment Protection Agency 1976; Richards et al. 1991; Patterson Schafer, Inc.1991; Polls et al. 1991a; Polls et al. 1991b). A BTI of 1.0 is defined as lethal to 50% of the bluegills exposed for 96 hr. Furthermore, experience has shown a BTI of 0.2 marks a carp-dominated community (BTI > 0.2) (Lubinski and Sparks 1981). Although there was a substantial decline in ammonia toxicity between 1975 and 1990, the trend of increased toxicity toward the Chicago area was still evident in 1990.

costs associated with replacing the functions once provided by the natural floodpulse of the river with human control (construction and maintenance of levees, operation of pumps and gates, production of fish in hatcheries for stocking in floodplain impoundments). Also, it is unlikely that the artificially maintained impoundments will provide the conditions necessary for maintenance of all the species of plants and animals that occurred in the natural river-floodplain ecosystem.

Amphibians and Reptiles

The herpetofauna of Illinois is relatively well known from Philip W. Smith's 1961 monograph *The Amphibians and Reptiles of Illinois*. This work was based on a systematic survey that critically evaluated all known collection records. Smith recorded 96 species in the state. Since 1961, distributions of many species have become significantly better known, and four additional species have been added to the state list (two salamanders newly discovered in the state and two frogs that previously had been confused with others). Previous statewide species lists include those of Davis and Rice (1883), Garman (1892), and Cagle (1941). Morris et al. (1983) provide an annotated bibliography of Illinois herpetological data since Smith through 1980.

Of the 100 species, 44 are represented in lotic systems (Tables 10 and 11). Disturbingly, at least one-third of these are currently at risk (Tables 10 and 11). Seven species are listed as threatened or endangered, and six more are on the watch list (two being considered for federal listing). As Smith (1961) pointed out, all of the herpetological habitats of Illinois are relict, because within historic times natural connecting habitats have been transformed into cities, industrial sites, cultivated fields, and greatly modified streams. No species is increasing its range or is becoming more abundant.

General Comments. Amphibians require more moisture than most other tetrapods and exhibit great diversity in habitat of the adults, mode of reproduction, and habitats of the young, reflecting a spectrum of dependence upon bodies of water. In Illinois, they are found in and along the edges of a variety of lotic and lentic waters, including lakes, ponds, and streams. They occur in streams of all sizes, from headwater springs and caves to the mouths of large rivers. Three of the completely aquatic stream salamanders never transform. Because the skin of amphibians is a major respiratory organ that functions only when covered with moisture, they are in intimate contact with environmental water and are sensitive to contaminants and siltation. Reduction or loss of amphibian populations is a significant signal of environmental degradation.

Many species of amphibians and reptiles live along the water/land interface, moving from one to the other as they eat and escape predators. Nearly all amphibians of lotic waters deposit aquatic eggs, and all have a larval stage lasting several months to a few years. Thus, their reproductive success and survival depend upon the availability of high-quality water containing suitable communities of food organisms.

Worldwide Decline in Amphibian Populations. There is worldwide concern that populations of amphibians are declining over broad areas around the earth. International symposia and workshops, spon-

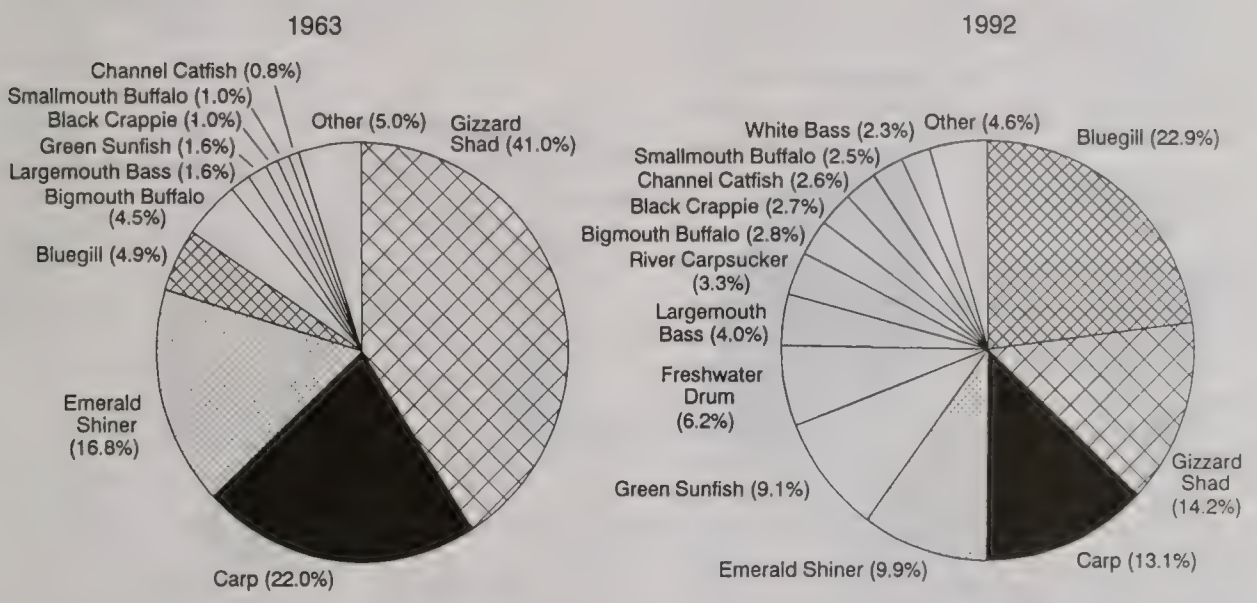


Figure 36. Percentages of catches by species for the middle Illinois Waterway, for 1963 and 1992, based on number of individuals collected per hour of electrofishing. In 1963, 10 species accounted for 95% of all fish collected per hour, and catches were dominated by gizzard shad, carp, and emerald shiner. In 1992, 13 species accounted for 95.4% of all fish collected per hour, with bluegill being the most abundant, while gizzard shad, carp, and emerald shiner were reduced in numbers in comparison to 1963. Overall, percentages for each species in 1992 were more evenly distributed than in 1963, indicating no single species overwhelmingly dominated catches. Species are arranged in descending order of relative abundance in a clockwise direction and are labeled separately until approximately 95% of the pie is filled.

sored among others by the National Science Foundation and the National Research Council, have focused on possible causes of decline and on strategies for obtaining relevant scientific documentation. Much of the decline is attributable to obvious destruction or degradation of natural habitats. Acid precipitation, pesticide release, agricultural practices, and exotic species introductions also have been implicated. In addition, amphibians are suspected to be particularly sensitive bioindicators of widespread, subtle ecological hazards such as increased ultraviolet radiation. Distinguishing the effects of these factors from natural fluctuations in populations has been particularly difficult because of the dearth of baseline data. Establishing a global monitoring program is a current effort of the ICUN Species Survival Commission's Task Force on Declining Amphibian Populations.

Mussels

Freshwater mussels (Unionidae) are often used as indicators of water quality and have often been compared to the "canary in the coal mine" in determining the health of the aquatic environment. Seventy-eight species of freshwater mussels have been reported from Illinois and boundary waters. Currently, only 63 species remain in Illinois, and 28 (44%) of those are considered to be either endangered (20 species), threatened (4 species), or on the watch list (4 species). Freshwater mussels are found in all of the medium to large rivers of Illinois and are occasionally present in creeks. Mussels are extremely long-lived, with some species reported to live over 50 years. They are filter feeders on detritus and plankton and constantly pump water through their bodies and sample their surrounding environment. One of the more interesting aspects of their biology is their dependence on freshwater fish in order to complete their life cycle.

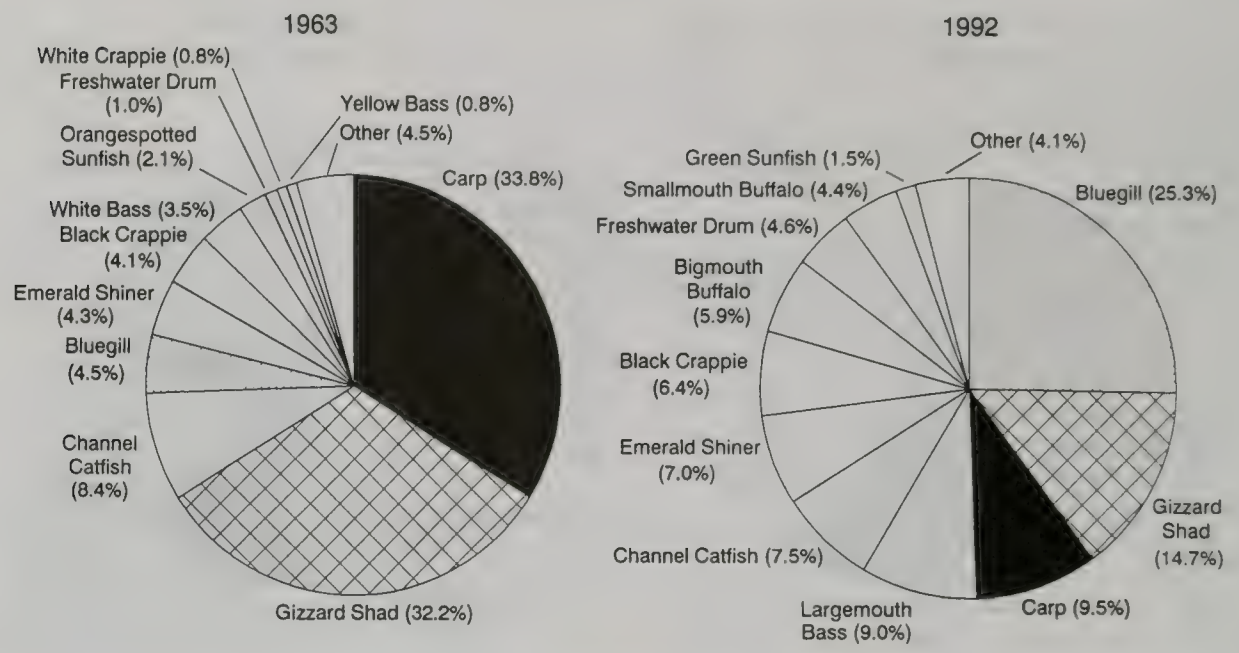


Figure 37. Percentages of catches by species for the lower Illinois Waterway, for 1963 and 1992, based on number of individuals collected per hour of electrofishing. In 1963, 11 species accounted for 95.5% of all fish collected per hour, with two-thirds of the catch being dominated by gizzard shad and the non-native carp (the most abundant fish). In 1992, 11 species accounted for 95.9% of all fish collected per hour; however, bluegill was the most abundant species. As in the middle waterway, percentages for each species in 1992 were more evenly distributed than in 1963, indicating no single species overwhelmingly dominated catches. Species are arranged in descending order of relative abundance in a clockwise direction and are labeled separately until approximately 95.5% of the pie is filled.

Illinois has a long history regarding the study of freshwater mussels. Thomas Say, one of America's first scientists and known as "the Father of Conchology" (the study of shells), first studied the mussels of the region in the early 1800s. Other scientists have conducted surveys and documented drastic declines in the freshwater mussel fauna over the past 175 years (Baker 1928, Parmalee 1967, Starrett 1971, Suloway et al. 1981).

Because of the diligence of earlier workers, we have excellent data on the known historical fauna of many of the streams of Illinois. We have information on the distribution and abundance of mussels from the 1950s and 1980s for four rivers in Illinois: the Embarras, Little Wabash, Sangamon, and Kaskaskia. Using the same sampling methodology in both studies, we have documented huge reductions in mussel populations in all streams surveyed to date. A pronounced decline in the number of species was found in the four rivers mentioned above from around the turn of the century to the 1950s (Figure 40). The number of species has remained fairly constant in the rivers studied from 1950 to 1990 with a slight increase in the Sangamon River and a decrease in the Kaskaskia River. The most pronounced reduction has come in the number of individual mussels found in these surveys (Figure 40). Some of the main factors responsible for the decline are siltation from agriculture and destruction of habitat through channelization and creation of impoundments.

While the vast majority of mussel species have shown pronounced declines, a few species, particularly those adapted to live in mud or silt bottoms, have expanded their range and numbers in Illinois in the past 30–40 years. These include the fragile papershell, *Leptodea fragilis*, the giant floater, *Anodonta grandis*, and the pink papershell, *Potamilus ohiensis*.

As mentioned in the section on commercial harvest, the greatest threat to the native Illinois mussel fauna may be the impact caused by the introduction of the zebra

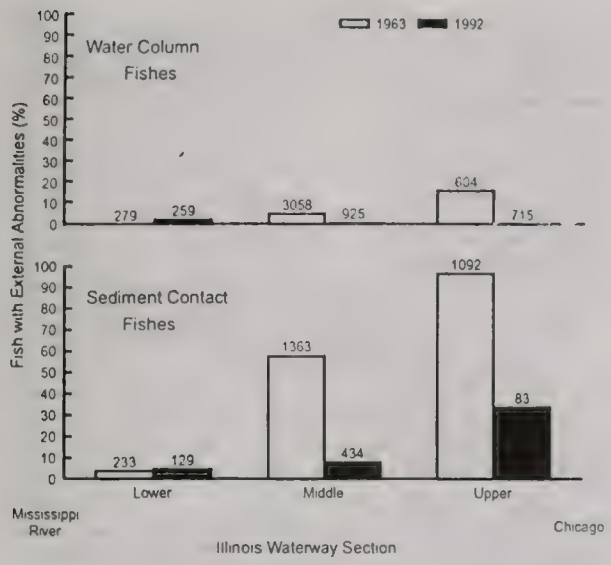


Figure 38. Incidence of externally visible abnormalities (sores, eroded fins, lumps) on fishes that mainly inhabit the water column (top figure) and on fishes that are likely to come into frequent contact with bottom sediments (bottom figure) for 1963 and 1992 in three sections of the Illinois Waterway. Numbers above each bar represent the total number of individuals caught for that river segment. Overall, for both years, the incidence of external abnormalities was higher on sediment-contact fishes than on water-column fishes, indicating irritating substances may be present in the sediments. The incidence of external abnormalities on sediment-contact fishes in both 1963 and 1992 and on water-column fishes in 1963 increased toward the Chicago area, implicating this area as the source of the factor or factors causing the abnormalities. Percentages were much lower in 1992 than in 1963, pratically disappearing in water-column fishes, indiating some reduction in the source.

mussel, *Dreissena polymorpha*, to the streams of Illinois. Another introduced species, the Asian clam, *Corbicula fluminea*, has been found throughout the state, although less frequently in the northern third. The effect of *Corbicula* on the native fauna is not well understood and is often debated.

Aquatic Insects

With the exception of mussels and clams, there has been very little recent attention paid on a statewide basis to the status of invertebrate communities in the streams and rivers of Illinois. Small isolated studies scattered in time and space cannot be effectively used to derive meaningful trends in the status of lotic invertebrates in Illinois. Given the extensive modification and/or degradation of stream habitats that has occurred over the past 30 years, we might expect trends among stream invertebrates similar to those of other aquatic groups; however, the relative sensitivities of these aquatic groups to various types of environmental modification can vary greatly.

The inability to discuss the current status of invertebrate populations in Illinois is unfortunate for at least two primary reasons. The first is that benthic invertebrates are generally excellent indicators of environmental quality because they have low vagility as larvae and generally exhibit quick responses to environmental change. (In comparison, fish have generally high vagility, and many are long-lived, so that it may take many years for the effects of environmental change to be obvious in fish communities). The second reason for regretting the paucity of information on the current status of stream invertebrate communities is that Illinois is unique nationally in having excellent historical data on aquatic insect distribution dating as far back as the 1860s. The comprehensive treatments of the Illinois fauna published by T.H. Frison (The Stoneflies, or Plecoptera, of Illinois. Illinois Natural History Survey Bulletin 20[4], 1935), H.H. Ross (The Caddis Flies, or Trichoptera of Illinois. Illinois Natural History Survey Bulletin 23[1], 1944), and B.D. Burks (The Mayflies, or Ephemeroptera of Illinois. Illinois Natural History Survey Bulletin 26[1], 1953) were landmark publications in their day and provide detailed accounts of where and when particular species were collected as well as some limited qualitative assessments of their abundance in streams throughout Illinois. These accounts, when taken together, give us a picture of conditions in Illinois streams during the 1920s, 1930s, and 1940s and provide an invaluable baseline from which changes to stream environments since that time can be assessed. These changes are

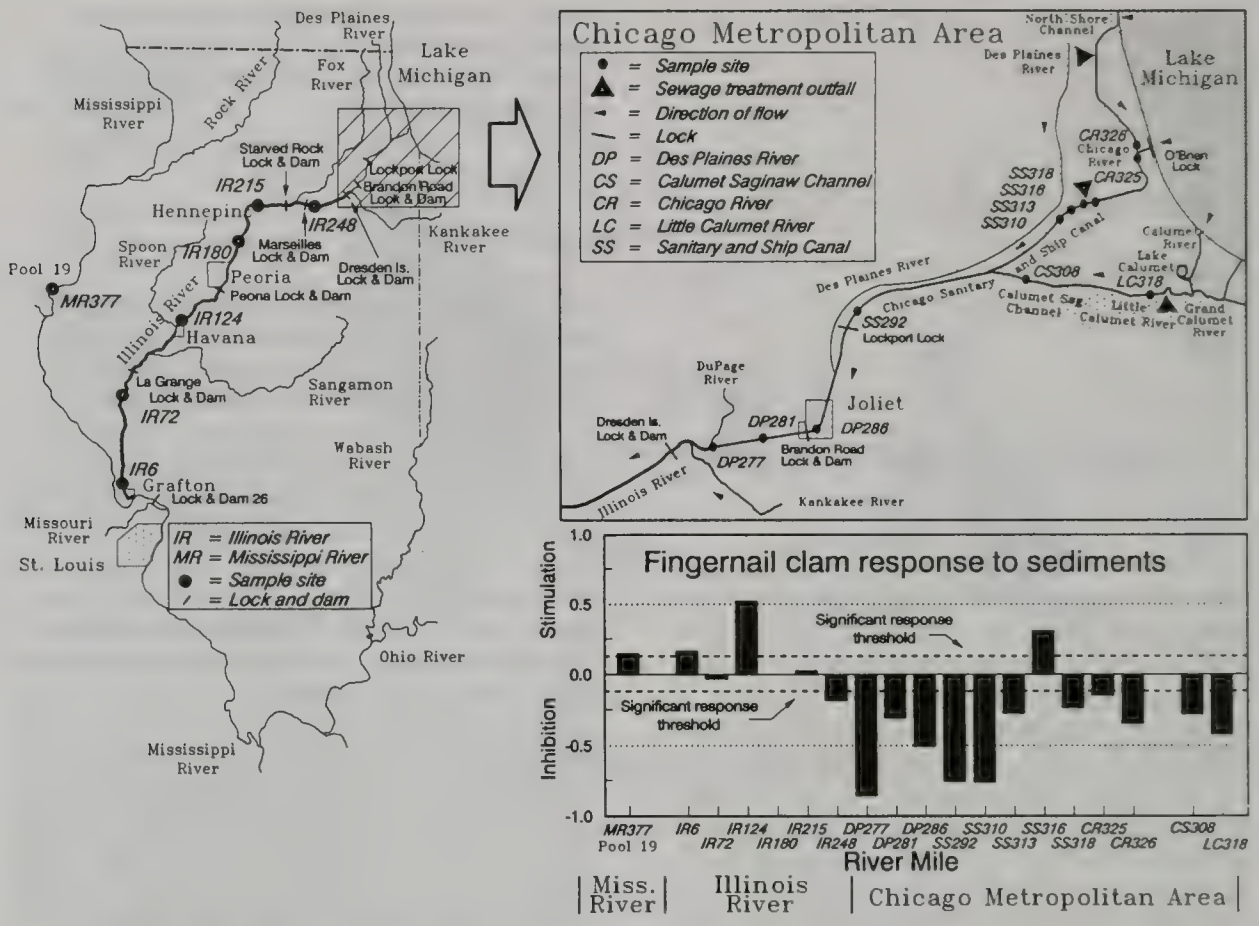


Figure 39. Response of fingernail clams to sediments collected in 1990 from the Upper Mississippi River, Illinois River, Des Plaines River, and Chicago waterways. Negative responses indicate toxicity and positive responses indicate stimulation. All the sediments from the Illinois River and Upper Mississippi River were nontoxic in these short-term tests (1 hour of exposure), whereas all the sediments from the Chicago area were acutely toxic, except for one sample from the Sanitary and Ship Canal at mile 316. More sensitive tests with fingernail clams have demonstrated toxicity even in sediments from the middle section of the Illinois Waterway (Sparks et al. 1981). The toxicity is largely attributable to un-ionized ammonia, with some contribution from petroleum hydrocarbons (Sparks et al. 1992). The fingernail clam was an important food organism for bottom-feeding fish and diving ducks in the middle and lower Illinois Waterway until it died out in the 1950s (Sparks 1984). As a result, the condition of bottom-feeding fish declined and diving ducks virtually ceased using the middle and lower waterway (Sparks 1984). The toxicity test measures how rapidly the clams remove food particles from water, following 1 hour of exposure to water extracted from the sediment samples. Reduction of feeding ultimately caused starvation and death of the clam. The horizontal dashed lines indicate significant response thresholds for inhibition or stimulation of feeding: 2 x the standard deviation + the mean difference in feeding rates determined in 18 control trials with no exposure to toxicants (Sparks et al. 1992).

Table 9. Mean relative weight (W_r) for bluegill and carp for 1963, 1975, and 1991.*

	Bluegill		Carp	
Year	N	Mean W_r	N	Mean W_r
1963	50	0.914	995	0.877
1975	123	0.984	449	0.781
1991	347	1.06	114	0.795

* W_r is determined by dividing an individual fish's weight by a length-specific standard weight (W_s), where W_s represents the top quartile of fish from a specific region (Murphy et al. 1991). A W_r equal to or greater than 1.0 indicates a healthy fish and, therefore, favorable ecological conditions, while a W_r less than 1.0 may indicate a food supply problem or some other factor (pollution stress) which is unhealthful to fish. Bluegill, which mainly inhabit the water column rather than foraging on the bottom, had a mean W_r close to 1.0 for 1963, 1975, and 1991, indicating that food supply may not be a problem for these species. In contrast, mean W_r's for carp, a bottom-feeding omnivore, were consistently less than 1.0 for all three years, indicating their environment may be less than conducive to healthy growth or that the food supply is limited in quantity or quality. Sparks (1984) and Starrett (1971) related the poor condition of bottom-feeding fishes to the lack of invertebrates (fingernail clams, aquatic worms and insects) on the bottom of the river. The lack of invertebrates is in turn linked to the occurrence of toxic levels of ammonia in the sediments (see Figure 38).

likely complex and will include both degradation (due to channelization, siltation, etc.) and improvement (due to increased treatment and control of human and industrial wastes) in stream environments since the 1940s.

It is virtually certain that many of the species reported by Frison, Ross, and Burks have been extirpated from areas where they formerly occurred; however, the extent to which this has occurred is unknown. For example, the unusual Pecatonica River mayfly (*Acanthometropus pecatonica*), listed as a candidate for protection under the Endangered Species Act, was originally collected in the Sugar and Pecatonica rivers in the 1920s but has not been seen there since and may well be extirpated from Illinois because of extensive channelization and degradation of small rivers. However, the status of the Pecatonica River mayfly and of many other potentially endangered stream invertebrates remains unknown. Currently, Illinois lists only one species of stream insect as endangered, although at least 11 federally listed species are known to have once occurred in Illinois. Many other stream species listed as state endangered or threatened in Wisconsin and other neighboring states also remain unlisted in Illinois, with their status here totally unknown.

Crayfishes

Data from a 10-year survey (Page 1985) of 1300 Illinois localities and historical information indicate that 23 crayfishes have been found at one time or another to be reproducing in the state. One species, *Cambarus robustus*, has disappeared during this century (Table 12), and two species, *Orconectes rusticus* and *Orconectes menae*, have been introduced.

Cambarus robustus was recorded from Illinois (Table 12) at the turn of the century but has not been found in the state since then. In the northeastern United States, it is found in cool rocky streams, and its presence in Illinois at the turn of the century may have represented relict populations left over from a more widespread distribution in a cooler postglacial climate. Its disappearance may have represented natural extinction in Illinois. However, other Illinois crayfishes are seriously threatened with extirpation (Table 12) as a result of the same factors negatively affecting fishes and other stream organisms: excessive siltation associated with agricultural practices; the drainage of bottomland lakes; water pollution; stream desiccation that follows the lowering of the water table as groundwater is removed for agriculture and municipalities; competition and predation by introduced species; and dams that convert streams into standing water.

Orconectes rusticus was first found in Illinois in 1973 and is rapidly expanding its range. *Orconectes menae* was first found in Illinois in 1992 and appears to be restricted to one stream in Greene County. Both species are used as fishing bait and probably were introduced into streams by fishermen. *O. rusticus* occurs naturally in northern Kentucky and southern Indiana. It has been introduced throughout much of northeastern United States and now is reproducing in almost all the states north of the Ohio River and east of the Mississippi as well as in Iowa, Missouri, and New Mexico. Until recently, *O. rusticus* was sold at bait shops in northern Illinois; however, possession of live *O. rusticus* is now illegal in Illinois. *O. menae*, native to southwestern Arkansas and eastern Oklahoma, probably was released in Illinois by a single fishermen.

Aquatic Vascular Plants

Aquatic macrophytes are an integral part of rivers and lakes. They diversify habitats for fish and fuel second-

Table 10. Illinois amphibians inhabiting lotic environments.

Species	Common Name	Habitat*	Status
Salamanders			
Cryptobranchus alleganiensis	Hellbender	P	Watch list
Notophthalmus viridescens	Newt	PS	Greatly reduced
Ambystoma texanum	Smallmouth salamander	PS, L	Widespread
Desmognathus conanti	Dusky salamander	H, S	State endangered
Eurycea cirrigera	Two-lined salamander	H, S	Locally common
Eurycea longicauda	Longtail salamander	H, S	Locally common
Eurycea lucifuga	Cave salamander	H	Locally common
Hemidactylium scutatum	Four-toed salamander	H, L	Watch list
Necturus maculosus	Mudpuppy	P	Uncommon
Siren intermedia	Lesser siren	P	Locally abundant
Frogs			
Acris crepitans	Cricket frog	S, PS	Locally abundant
Rana blairi	Plains leopard frog	PS	Uncommon
Rana catesbeiana	Bullfrog	S, PS	Common
Rana clamitans	Green frog	S	Common
Rana palustris	Pickerel frog	H, PS	Uncommon
Rana pipiens	Northern leopard frog	S, PS	Locally common
Rana utricularia	Southern leopard frog	S, PS	Common

* H = headwaters, spring-fed streams, or caves; S = streamside; L = only during larval stage; PS = ponded streams, ponds, and marshes; P = permanently aquatic adults. All have an aquatic larval stage that may be found in lotic waters.

ary production by producing organic matter, cycling nutrients, and providing cover for fishes and substrate for fish food organisms. Since human settlement, there has been a decline in aquatic macrophytes in riverine systems. This section describes changes in aquatic macrophyte populations in three large rivers.

Illinois and Mississippi Rivers. Aquatic vegetation in large floodplain–river ecosystems is very dynamic and closely linked to the hydrology and water quality of the river. Through the 20th century, aquatic vegetation was observed to decline throughout the Illinois River ecosystem. Pollution, intensive agriculture, and navigation lead to poor water quality and high rates of sedimentation and sediment resuspension that limits light penetration necessary for growth and establishment of aquatic plant beds. High rates of sedimentation and artificially high water levels, necessary for modern river navigation, also result in sediment deposition in backwater lakes, creating flocculent sediments in which plants have difficulty rooting. Some signs of recovery are reported by staff at the Illinois Natural History Survey's Long Term Resource Monitoring Program (LTRMP) Field Station at the LaGrange Pool of the Illinois River. They have found submersed aquatic plants appearing in areas where they have not been found for many years.

Aquatic plants in the Mississippi River follow a north-south gradient, with aquatic plants being more diverse and more numerous in the north. Relatively low rates of sedimentation in the upper reaches of the river provide conditions favorable to the development of aquatic plants. Increased rates of sedimentation from Illinois and Iowa farms reduce light penetration through the water and subsequently reduce the amount of aquatic plants found in the southern parts of the river.

Monitoring of aquatic vegetation at the Illinois Natural History Survey's LTRMP Field Station at Pool 26 of the Mississippi River has provided data necessary to evaluate some of the mechanisms controlling aquatic vegetation distribution in the upper river. Submersed aquatic vegetation was abundant in some portions of Pool 26 in 1989 (Figure 41). Stable water levels (Figure 42) and reduced sediment input, resulting from a two-year drought, created conditions favorable to the

Table 11. Illinois reptiles inhabiting lotic environments.

Species	Common Name	Habitat*	Status
Turtles			
Chelydra serpentina	Common snapping turtle	C	Common
Macroclemys temmincki	Alligator snapping turtle	C	Watch list
Kinosternon flavescens	Illinois mud turtle	A	Endangered
Kinosternon subrubrum	Eastern mud turtle	A	Rare
Sternotherus odoratus	Common musk turtle	C	Common
Chrysemys picta	Painted turtle	A	Common
Clemmys guttata	Spotted turtle	A	Endangered
Emydoidea blandingi	Blanding's turtle	A	Watch list
Graptemys geographica	Common Map turtle	C	Uncommon
Graptemys pseudogeographica	False map turtle	C	Locally common
Pseudemys concinna	River cooter	C	Endangered
Trachemys scripta	Slider	A	Abundant
Apalone mutica	Smooth softshell	C	Watch list
Apalone spinifera	Spiny softshell	C	Common
Snakes			
Clonophis kirtlandii	Kirtland's snake	A	Watch list
Farancia abacura	Mud snake	A	Uncommon
Nerodia cyclopion	Mississippi green water snake	A	Threatened
Nerodia erythrogaster	Plainbelly water snake	A	Locally common
Nerodia fasciata	Broad-banded water snake	A	Endangered
Nerodia rhombifer	Diamondback water snake	A	Locally common
Nerodia sipedon	Northern water snake	A	Common
Regina grahami	Graham's water snake	A	Uncommon
Regina septemvittata	Queen snake	A	Uncommon
Thamnophis proximus	Western ribbon snake	A	Common
Thamnophis sauritus	Eastern garter snake	A	Endangered
Agkistrodon piscivorous	Cottonmouth	A	Locally common

* C = adults completely aquatic except for egg laying, hibernation, and dispersal), A = amphibious, moving in and out of water.

development of submersed aquatic plant beds. When typical water levels (Figure 43) and runoff rates returned, those beds disappeared (Figure 44). The degree of change is summarized in Figure 45. Similar changes were reported by the LTRMP Field Station at Pool 13 (Michael Griffin, Iowa Department of Natural Resources, personal communication). The major differences between the two locations is that Pool 13 has extensive aquatic vegetation beds in most years whereas Pool 26 has extensive vegetation beds only during drought years. The LTRMP Field Station in the unimpounded portion of the river, near Cape Girardeau, Missouri, has never documented aquatic plants in that portion of the River (Yao Yin, Missouri Department of Conservation, personal communication).

Des Plaines River. To assess the extent and track the changes in aquatic macrophyte coverage in the Des Plaines River (river miles 273–286; see Figure 46), aerial photographs and ground truth surveys were carried out annually from 1985 to 1991 (Tazik and Sobaski 1992) About 65% of the total 693 ha of water surface area, or 450 ha, is potentially habitable by submersed and emersed vegetation. Vegetation coverage in this reach has fluctuated dramatically over the past seven years (Figure 47). During earlier surveys 10–13% of the 450 ha was vegetated; in 1991 the vegetated areas constituted 6% of the potentially habitable areas. Peak vegetation levels (60 ha) were reached in 1987, and since then there has been a steady decline to the estimated 27.5 ha in 1991 (Figure 47).

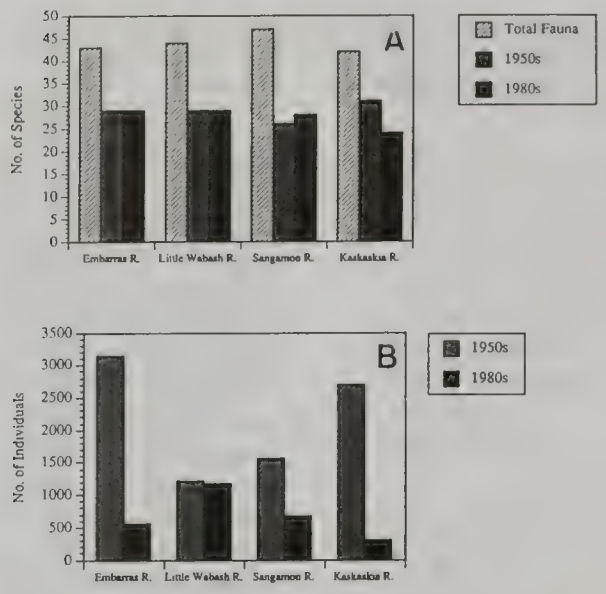


Figure 40. (A) Number of mussel species known to have occurred in four rivers in Illinois and the number of species present in the 1950s and the 1980s. (B) Abundances of mussels in the 1950s and 1980s in the Embarras, Little Wabash, Sangamon, and Kaskaskia rivers.

Table 12. Extirpated and endangered species of native Illinois crayfishes and their former or present distribution.

Species	Distribution
Extirpated	
Cambarus robustus	Quincy (Adams Co.), Decatur (Macon Co.)
Endangered	
Orconectes indianensis	Southeastern Illinois
Orconectes kentuckiensis	Southeastern Illinois
Orconectes lancifer	Southern Illinois
Orconectes placidus	Southern Illinois

Concomitant with this decrease in vegetation cover has been a shift in relative importance of heavily vegetated areas within the reach (Figure 48). The most dramatic decrease has occurred in the area just upstream of the confluence of the Des Plaines and Kankakee rivers (Segment 6) (Figure 48), where in 1985–1987 there was an average of 8.85 ha of vegetation, and in 1991 there was less than 1 ha.

In addition to an overall drop in coverage, there has been a dramatic shift in the species composition. This shift in species composition in Segment 6 has resulted in *Myriophyllum spicatum* becoming a more important part of the community dominating several areas of the reach (Tazik and Sobaski 1992). There has been a decrease in *Potamogeton crispus*, *P. nodosus*, *P. pectinatus*, and *Vallisneria americana*. Emersed vegetation species composition has remained relatively stable with *Typha* spp. and *Sagittaria latifolia* remaining dominant (Tazik and Sobaski 1992).

Most probable explanations for the declines in coverage and shifts in species composition are the physical factors of the reach and the 1988 drought and carryover conditions (Figures 47 and 48). Although results of chemical analyses indicate that, in general, there have not been substantial changes between 1987 and 1991 in element levels in sediments, and probably not in macrophyte tissues, there are significant differences in the toxicity of sediments between sampling sites (Tazik and Sobaski 1992). Furthermore, although there has been a significant decline in the concentrations of barium, copper, and mercury, the sediments throughout this reach are subject to considerable pollution and have had notably toxic sediments.

RESTORATION AND PROTECTION

This section catalogues stream habitat management projects on streams other than the Mississippi and Illinois rivers. Stream habitat management projects can be divided into four categories, starting with protection projects, which seek to protect existing habitat from degradation. Restoration projects are aimed at restoring aquatic habitat by reversing degradation. Habitat enhancement efforts are meant to improve habitat, usually for one or two species of sport fish. The objective of an erosion control project is to stabilize a stream channel. Stream management projects usually include elements of more than one of these categories; for example, a restoration project may be aimed at erosion control. Although stream restoration projects are usually thought of as physical manipulations of streams, they can be passive as well; that is, destructive forces can be removed and streams allowed to heal with time.

Figure 49 shows current stream habitat management projects in Illinois. A designated 17-mile section of the Middle Fork of the Vermilion River is Illinois' only federally designated National Wild and Scenic River.

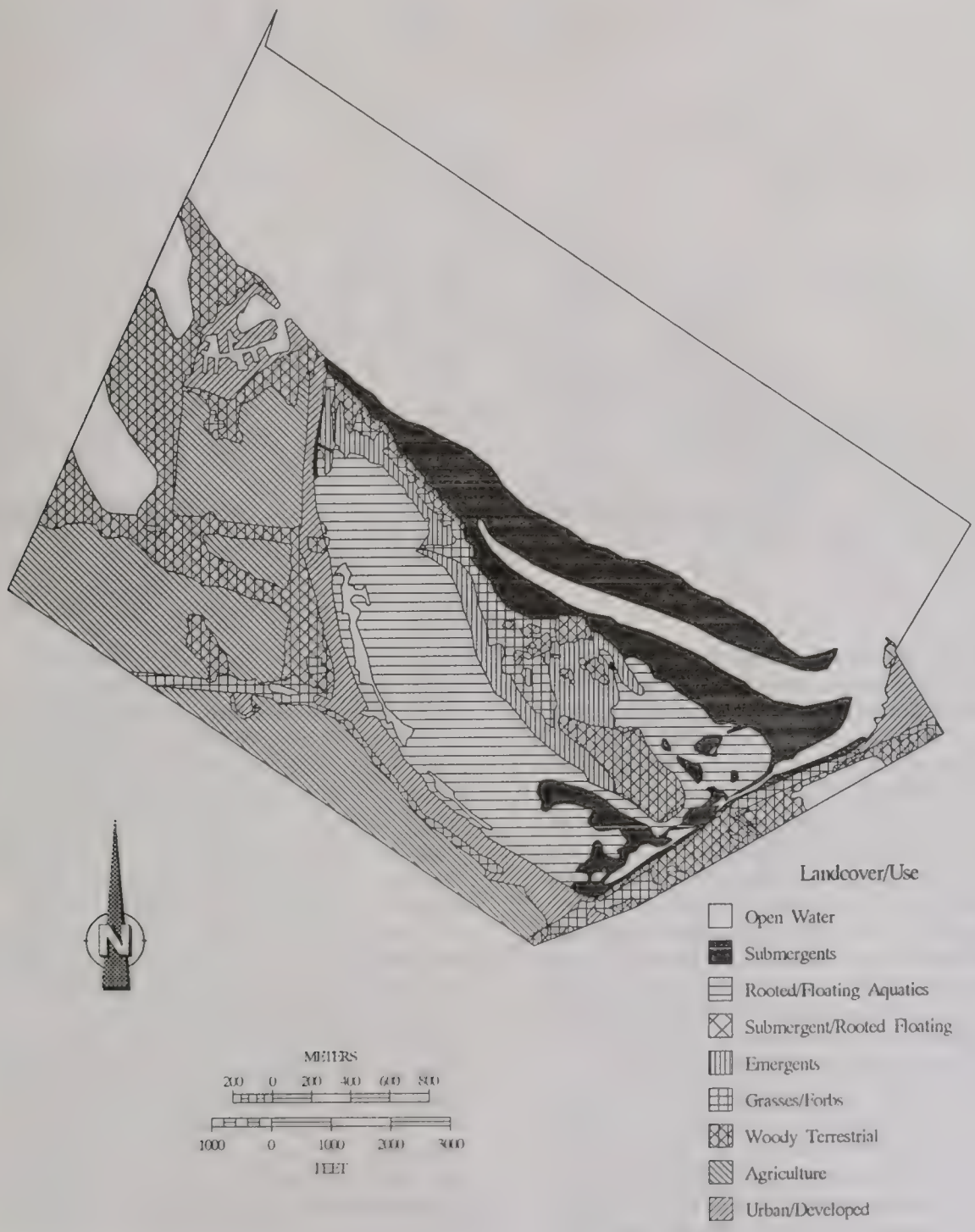


Figure 41. Land cover/use at Pool 26 of the Mississippi River in 1989.

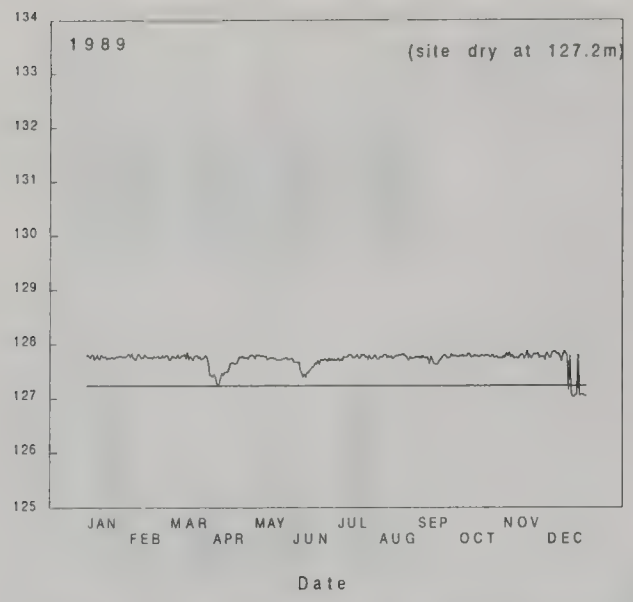


Figure 42. Hydrograph (stage height) of the Mississippi River at Alton, Pool 26, in 1989.

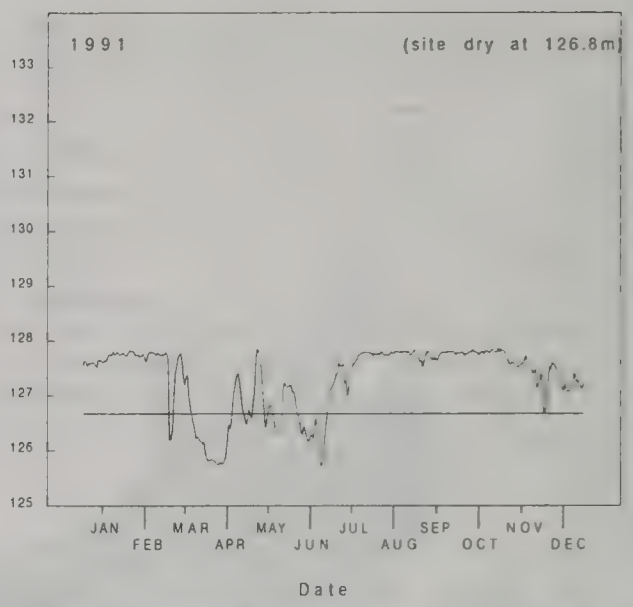


Figure 43. Hydrograph (stage height) of the Mississippi River at Alton, Pool 26, in 1991.

This section is also a designated State Protected River (Illinois Department of Conservation 1992). The Illinois Nature Preserves Commission has established nature preserves on the Little Vermilion and Cache rivers. Figure 49 also shows structural habitat management projects in Illinois. These are primarily aimed at erosion control but include fish habitat enhancement elements. Stream habitat management of this kind is relatively new in the state. The oldest of these projects, on Crow Creek, was initiated in 1986. All of these projects were initiated by Donald Roseboom (Illinois State Water Survey), and most involved cooperation with the Illinois Department of Conservation. Structures used in these projects include "lunkers," which are wooden, rock-covered devices used to prevent bank erosion and provide overhead cover for fish (Roseboom et al. 1992), and tree revetments, which are rows of trees anchored along streambanks to prevent erosion and encourage the growth of riparian vegetation. Live booms are rock and soil jetties in which willow cuttings are placed. Willow posts are large willow cuttings (about 12 feet long) that are planted upright in stream banks. The root systems of these plantings help stabilize streambanks, and their stems, branches, and leaves protect banks and provide food and cover for terrestrial and aquatic wildlife. A-Jacks are prefabricated concrete structures that resemble the toys of the same name and are used in conjunction with willow cuttings to stabilize eroding streambanks (Donald Roseboom, personal communication).

Many, if not most, Illinois streams are markedly degraded from their presettlement condition. As past management of these streams is reevaluated, the demand for restoration knowledge is increasing. As an example, ditching, channelization, and devegetation of streams for flood control is now understood to have been only partially effective in some watersheds and ineffective in others. The legacies of this management can in many cases be corrected by restoration. Current research is limited in scope (e.g., Roseboom et al. 1992) and is only a first step in meeting the needs for restoration knowledge in Illinois. Pressing questions center on multiobjective management and concern, for example, the effects of channelization on stream ecosystems and how streams might be better managed for aquatic habitat without limiting their effectiveness in conveying floodwaters. The historical conditions of Illinois streams are poorly understood, although such information is necessary to know to what condition they should be restored. Finally, restoration methodology suitable for the unique zoogeographic and physiographic regions of Illinois must be further developed and tested.

SUMMARY AND RECOMMENDATIONS

The biodiversity of Illinois' flowing waters has been markedly altered during the 20th century. Substantial numbers of fish, amphibian and reptiles, and inverte-

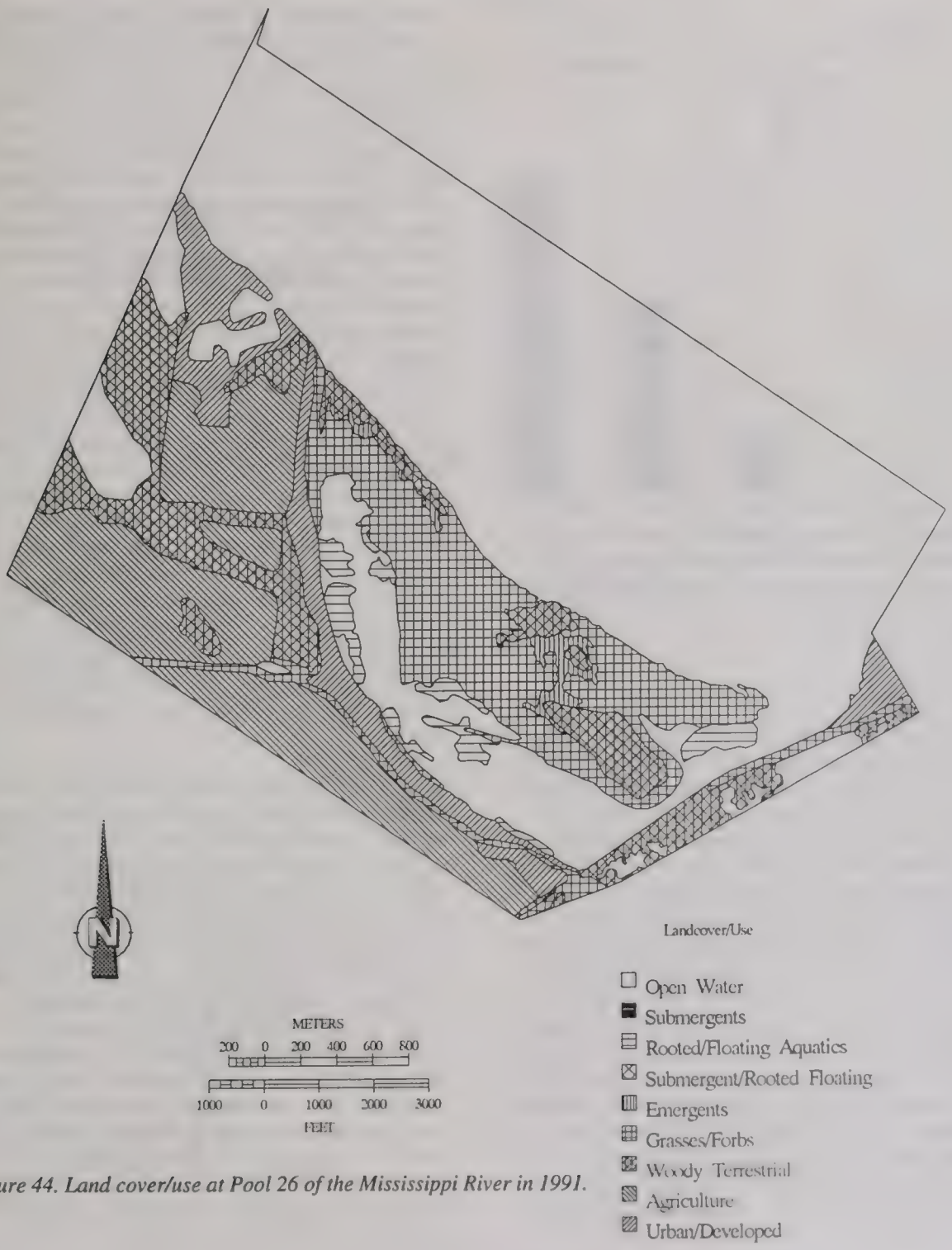


Figure 44. Land cover/use at Pool 26 of the Mississippi River in 1991.

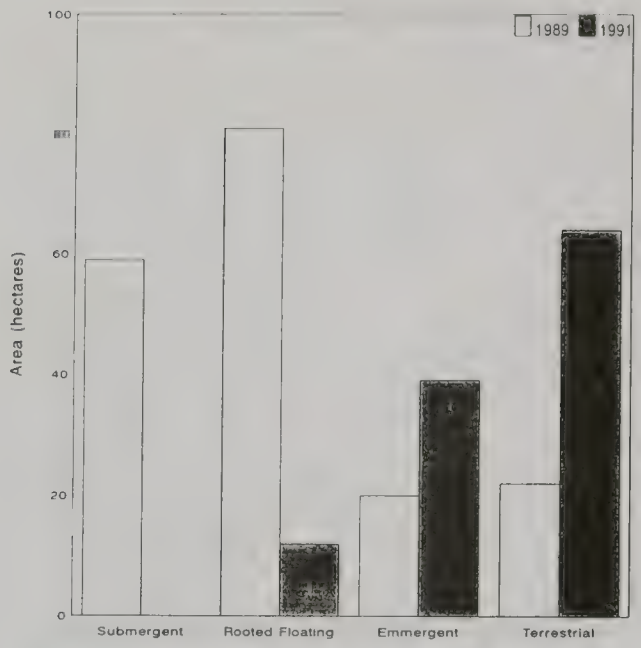


Figure 45. Coverage by aquatic (submerged, rooted / floating, emergent) and terrestrial vegetation at Pool 26 of the Mississippi River at Alton in 1989 and 1991.

brate species that inhabit running waters have been extirpated in Illinois since 1900. Thirteen species of fish (7% of the fauna present at the start of the century) no longer exist in Illinois, while an additional 23 species (12.3% of the fauna present in 1900) are listed as threatened or endangered and are in danger of being extirpated. Fewer amphibians or reptiles have been extirpated in Illinois (only 1 of 44 flowing-water species), but about 33% of the remaining species are at great risk of being lost because of declining populations. By far the worst situation known is for the freshwater mussels; 15 species (19% of the "original" fauna) are now extinct in Illinois while an additional 28 species (44% of the current fauna) are considered to be at considerable risk of extinction in Illinois. Therefore, over half (55%) of Illinois' mussel species either are no longer present in Illinois or are in danger of being eliminated from the state. Finally, nearly 22% of Illinois' crayfishes either no longer exist in Illinois or are endangered.

Unfortunately, similar information is not available for other groups of organisms that inhabit flowing waters. This is especially troublesome for two groups—aquatic insects and plants (algae and macrophytes)—that are functionally extremely important in stream ecosystems.

Recent evaluations of the biotic integrity (or health) of Illinois' streams and several long-term studies suggest that it should not be surprising that such a high proportion of its flowing-water fauna should either be extinct or in danger of extinction in Illinois. Using biological criteria to assess the condition of streams shows that the proportion of stream miles in Illinois of moderate to very poor quality greatly exceeds the proportion rated as good to excellent. Unfortunately, similar earlier statewide evaluations of the quality of Illinois' streams were not performed. Nonetheless, earlier workers (e.g., Ross [1944]) who sampled extensively throughout the state lamented about the overall quality of streams in Illinois and noted that a very high proportion of the streams had been appreciably manipulated. Interestingly, Ross (1944) did not refer to effects of urbanization, especially the effects of organic effluents such as sewage, as being major causes of poor stream quality. Rather, he considered landscape manipulations within watersheds (e.g., removal of riparian vegetation, agricultural practices leading to increased erosion from farmlands, channelization of streams) to be the major factors affecting stream quality. Unfortunately, we do not have data on long-term trends in many land use practices within watersheds and are, therefore, unable to associate such trends with current assessments of stream quality.

Despite Ross' (1944) comments, discharge of sewage effluents into streams strongly affected stream quality, especially in the first 60–70 years of this century. Two long-term studies of fish populations (Illinois River; streams in Champaign County) have documented improvements in stream quality (based on the status of fish populations) over the past 30 years that are likely the result of improved treatment of sewage discharged into streams. Especially noteworthy are marked improvements in functionally and economically important piscivorous populations (e.g., smallmouth and largemouth bass, channel catfish) in both studies. Nonetheless, the current status of fish populations in both systems indicates that significant problems persist. In the upper Illinois River, bottom-dwelling fishes have poor body condition and a high incidence of external abnormalities, suggesting a continuing problem with sediments, which are known to be toxic to the invertebrates on which these bottom-dwelling fishes feed. In Champaign County, the frequency with which species that are tolerant of poor habitat quality are encountered has increased over the past 90 years.

Similar improvements have not been noted for mussel populations from four rivers in east-central Illinois for

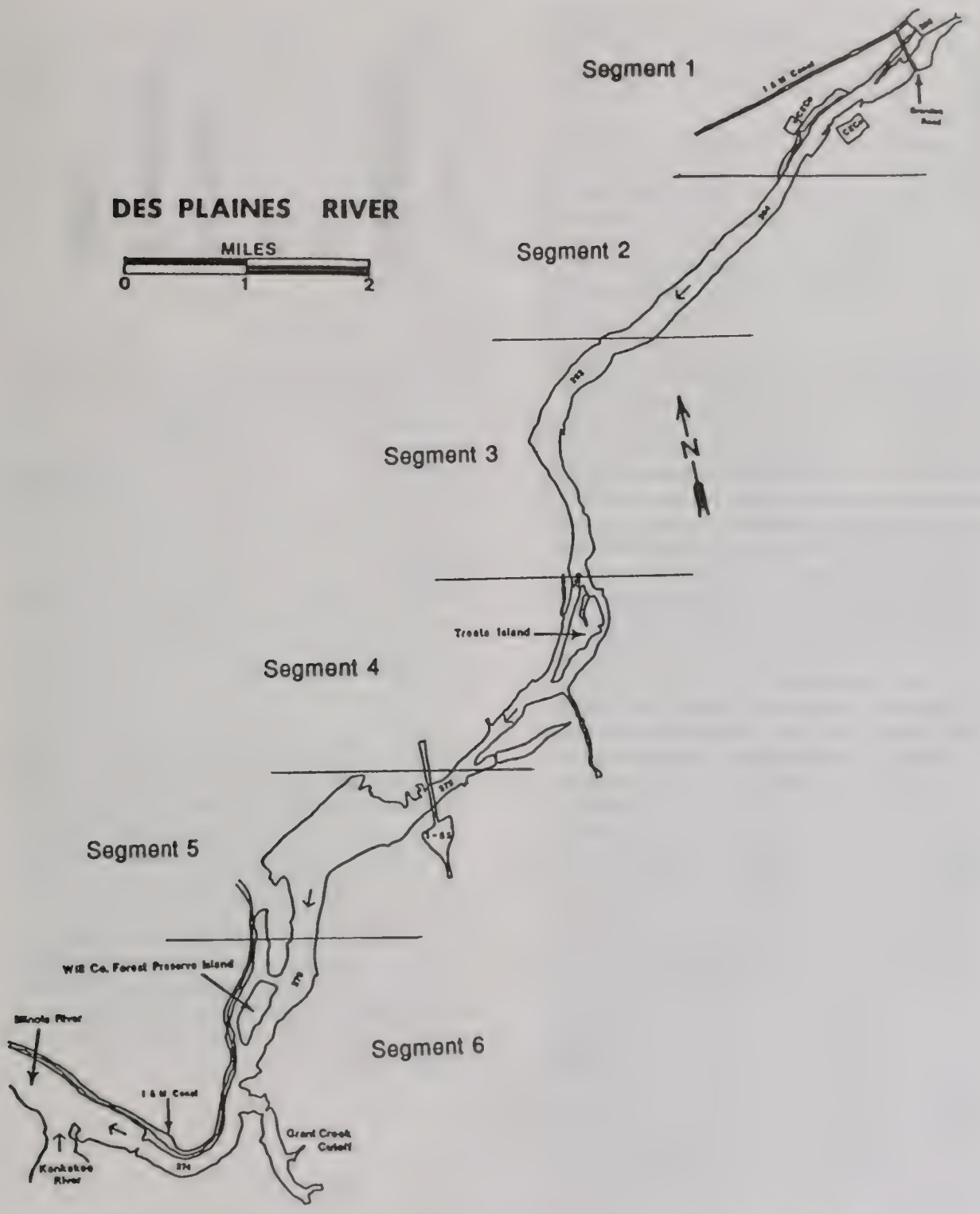


Figure 46. The Des Plaines River study reach including river miles 273 through 286 in Will and Grundy counties, Illinois.

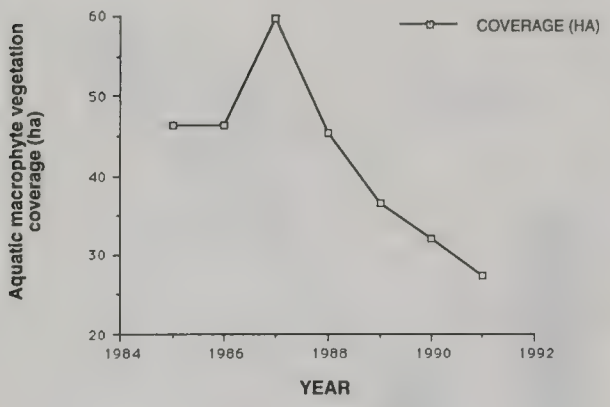


Figure 47. Vegetation cover in the lower Des Plaines River (river miles 273–286) during the past seven years. About 65% of the total 693 ha of water surface area, or 450 ha, is potentially habitable by submersed and emersed vegetation. This includes main channel border, slough, and side channel areas but excludes the main navigation channel. During earlier surveys 10–13% of the 450 ha was vegetated; in 1991 the vegetated areas constituted 6% of the potentially habitable areas. Peak vegetation levels (60 ha) were reached in 1987, and since then there has been a steady decline to the estimated 27.5 ha in 1991. The above graph demonstrates the significant decline in total vegetation cover in the lower Des Plaines River from 1985 to 1991. There are a number of hypotheses to explain the decrease in plant populations in the study reach, most relating to physical factors. The drought of 1988, and carryover of those conditions to a lesser degree in 1989, may explain some of the decline in coverage. Decreased water depths both during the drought and afterward, resulting from increased sediment deposition due to poor watershed management, may account for some of the most significant decreases in vegetation cover. With decreases in water depth it is likely that much of this area became too shallow to support submersed vegetation. Drought conditions in 1988 may have caused barge traffic to increase. Low water levels may have necessitated an increase in the total number of barges handling smaller individual tows to avoid running aground with more traditional larger tows. Under this scenario, the frequency of disturbance would increase although the magnitude would decrease, which may affect aquatic vegatation more severely.

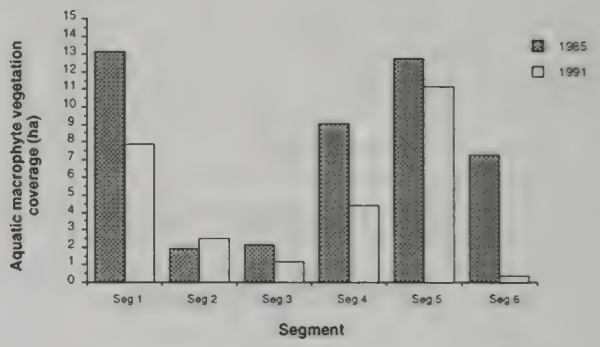


Figure 48. Changes in vegetation cover in various segments of the lower Des Plaines River, 1985 to 1991. The most dramatic decrease occurred in the area just upstream of the confluence of the Des Plaines and Kankakee rivers (segment 6), where in 1985–1987 there was an average of 8.85 ha of vegetation, and in 1991 there was less than 1 ha (see Figure 46). Total vegetation cover in segment 1 (Brandon Road) fluctuated between 4.3 and 13 ha during the monitoring period; the nearly 8 ha present in 1991 represented an increase over the 4–5 ha documented in 1988–1990. Vegetation in segment 4, the side channel near Treats Island, has decreased consistently sonce 1985. Significant differences in sediment toxicity of these sampling sites have been found but do not account for the site variability in vegetation cover. Again, the physical differences of the segments and the impact of the 1988 drought are more likely the cause for the differences in vegetation cover in each of the segments. Results of chemical analysis indicate that, in general, there have not been substantial changes between 1987 and 1991 in element levels in sediments, and probably not in macrophyte tissues, although sample size was limited. Furthermore, although there has been a significant decline in the concentrations of barium, copper, and mercury, the sediments throughout this reach are subject to considerable pollution and have had notably toxic sediments.

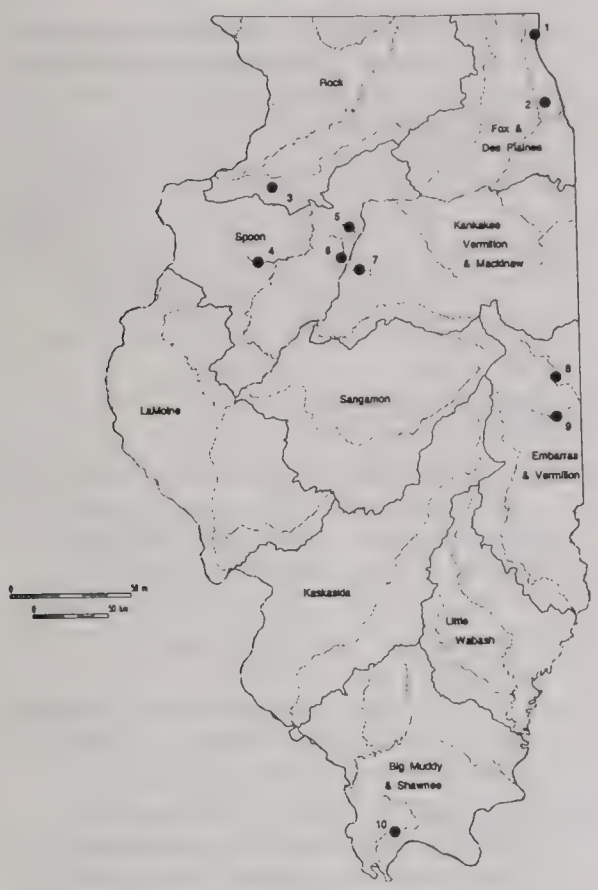


Figure 49. Restoration and protection of rivers and streams in Illinois, excepting the Mississippi and Illinois rivers, and methods used. (1) Waukegan River, lunkers and A-jacks (see text for description of structures); (2) Glen Crest Stream, lunkers and A-jacks; (3) Franklin Creek, lunkers and tree revetment; (4) Court Creek, will posts and lunkers; (5) Crow Creek, live booms with willow facines and willow posts; (6) Sanachwine Creek, willow posts; (7) Richland Creek, willow posts; (8) Middle Fork of the Vermillion River, National Wild and Scenic River System and State Protected River, protection only; (9) Little Vermillion River, Illinois Nature Preserve; (10) Cache River, Lower Cache River State Natural Area.

which there are long-term records. In all four rivers, large reductions in populations of most mussel species have occurred over the past 40 years, apparently due to increased siltation and loss of suitable habitat.

Mussel populations in Illinois' largest rivers, the Mississippi and the Illinois, face similar threats and also must contend with exploitation by humans for the cultured pearl industry. Commercial harvest of mussels in these rivers increased dramatically between 1987 and 1990. Without fundamental information on vital rates for harvested populations, it is unclear whether these populations can sustain such high rates of exploitation. Similarly, it is unclear whether commercially harvested fish populations in the Mississippi, Illinois, Kaskaskia, and Wabash rivers are being overexploited.

Mussel populations may also be affected by exotic species, such as the zebra mussel and the Asiatic clam. Similar problems face other invertebrates (e.g., crayfish), fish, and macrophytes. Perhaps more important than their effects on individual species populations, exotic species can also markedly affect ecosystem structure and function. Little information exists for *any* of these in Illinois.

Numerous areas requiring additional research are evident from the preceding discussion. The following general areas are in particular need of immediate attention:

- Considerably more data are needed on the population dynamics of harvested species so that allowable harvest rates can be better determined.

- Research on the anticipated effects of exotic species on species populations and on ecosystem-level properties is needed to develop management plans.

- Long-term studies need to be established on functionally significant groups in lotic systems (e.g., aquatic insects, crayfish, plants) for which little long-term data exist. Long-term studies on other populations (e.g., fish, mussels) need to be expended to include a broader range of systems represented in Illinois.

- Much more research on the ecology of large rivers is greatly needed. Considerably less is known about the mechanisms affecting the structure and function of such systems relative to smaller streams. In particular, the effects of manipulations within the floodplain (e.g., levee construction) and within the stream channel (e.g., navigation dams, navigation traffic) need further

attention. An experimental approach, although difficult to take on such large systems, would be advisable in many circumstances. For example, destruction of levees on several large rivers by the Great Flood of 1993 provides a unique opportunity to experimentally address the effects of such structures on population-, community-, and ecosystem-level properties. Appropriate agencies should consider appropriating funds for such research immediately.

Restoration, protection, and management of Illinois' streams requires the adoption of a large-scale perspective (i.e., watershed-level or basin-level) regarding the structure and function of stream ecosystems. Stream reaches tend to be managed as though they were independent of upstream or downstream reaches within the watershed or drainage basin. This practice ignores virtually everything that is known about how stream ecosystems work. Any given segment of stream is strongly influenced by things occurring within the segment *and* by things occurring upstream of the segment in the watershed and downstream (e.g., from damming). Few perturbations to streams can be considered to be processed locally, within a stream segment (e.g., sewage effluents), and, consequently, to have little influence on downstream segments. Most other perturbations that appear to be markedly affecting Illinois streams (e.g., land-use practices affecting stream morphology, sedimentation, inputs of polluting chemicals such as plant nutrients, herbicides, pesticides, and other toxic chemicals) cannot be considered to be "processed" within a given stream segment, in part because the inputs (of sediments, chemicals) generally are not localized and because many perturbations (e.g., inputs of sediments) are more or less biologically inert and, therefore, are not "processed" at all.

Similar to this expanded longitudinal perspective is that, in larger streams, an expanded lateral perspective should also be adopted. Larger streams are intimately connected in terms of morphology, hydrology, structure, and function with their floodplains as well as with upstream reaches within the drainage basin. Management of large rivers in Illinois and elsewhere has expressly attempted to uncouple this link between the river and its floodplain, largely through the construction of levees and dams. The consequences of such attempts can be disastrous for humans (e.g., the Great Flood of 1993) as well as for the biota of large rivers, although more research in this area is urgently needed.

The bottom line is that, for example, management of a larger stream must consider what is occurring *throughout* the drainage basin, especially upstream of the area of interest and immediately downstream, and laterally within the floodplain. Therefore, management of large streams requires management of their tributaries throughout the drainage basin. Adoption of such a perspective will not be easy. For example, the structure, function, and utilization of drainage districts will have to be dramatically altered. However, *only* through the adoption of such a perspective will we be able to improve stream quality and preserve and protect existing high-quality streams in Illinois.

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RESOURCE ANALYSIS

SUMMARY

Environmental assessment should include a status report on renewable and nonrenewable resources. For a renewable resource, we ask whether the stock (the "natural capital") is maintained so that the resource *is* truly renewable. For a nonrenewable resource, we ask how long we can expect the resource to last at the anticipated rate of consumption. We address these questions for the following:

- **Renewable resources**
  - Soil
  - Forests
  - Ethanol
- **Nonrenewable resources**
  - Coal
  - Oil
  - Natural gas

We also scrutinize trends in:

- **Pollution**
  - Energy/CO_2 production
  - Fossil/solar energy
- **Consumption and lifestyle**
  - Motor vehicles
  - Recycling

This list is only a beginning for future, more complete accounting.

For resources, the most basic indicator is static lifetime, which is the length of time the resource will last at today's consumption rate and today's discovery or replenishment rate. We acknowledge three difficulties with this approach:

1. Future consumption will change. If it increases, the lifetime is less than the static lifetime.
2. The "amount of resource" is an imprecise number that depends on economic conditions and on technological change.
3. The efficiency with which we use the resource can change, so that static lifetime is an imperfect indicator of the useful lifetime to citizens.

Additionally, we note that the amount of a resource should be balanced against the consequences of using it. The static lifetime for Illinois coal used to satisfy Illinois demand is measured in hundreds of years, which is auspicious, yet coal combustion yields more carbon dioxide per unit of energy than any other fuel, which is problematic.

We find:

- **Renewable resources**

Soil. On average, erosion rates are so small (approximately 0.03 inches/year) that Illinois soil will last hundreds of years. However, this varies across counties; some are so steep and eroding so fast that the soil lifetime is just several decades. Erosion rates decreased from 1982 to 1987. In many counties, the percent change in cropland acreage exceeds the percent change in soil depth from erosion; in that case it is land-use change that dominates the change in the "volume" of available soil.

Forests. Wood volume increased from 1962 to 1985. Harvest rates increased, however, so that net accumulation in 1985 was negative.

Ethanol. Ethanol production has grown over the past 15 years to now equal approximately one-sixth of Illinois' liquid road fuel use. Net energy considerations complicate considering this fuel renewable, however.

- **Nonrenewable resources**

Coal. Illinois has enough coal for approximately several hundred years' in-state consumption at current rates.

Oil. Illinois has enough oil for approximately one year's in-state consumption at current rates.

Natural gas. Illinois' reserves are very small and not formally evaluated. Illinois' annual production (as a byproduct of oil production) is approximately 0.1% of its in-state consumption.

- **Pollution**

Energy/CO_2 production. Illinois uses approximately 1% of the world's energy and produces approximately 1% of the world's energy-related CO_2. In the 1980s energy consumption decreased, with the decrease dominated by reduced oil consumption following large increases in the world oil price. The ratio of CO_2 to energy decreased in the period 1960–1990 because of (1) a trend away from coal toward oil and natural gas in 1960–1980 and (2) an increase in the amount of electricity produced from nuclear power plants in 1970–1990.

A simple projection to the year 2000 shows Illinois energy use holding steady or increasing slightly, but a decrease is possible depending on economic growth and increased energy efficiency.

Fossil/solar energy. This ratio is a broad, approximate indicator of overall environmental impact. In Illinois, fossil energy consumption amounts to about 6% of the incoming solar energy at the ground. This ratio is 600 times higher than in the world as a whole. Indirect evidence indicates that in highly urbanized areas, the fossil/solar energy ratio is approximately 1.

- **Consumption and lifestyle**

Motor vehicles. Vehicles use 24% of Illinois' energy and produce 29% of its energy-related CO_2. While human population growth in Illinois was 0.0036% per year during 1980–1990, the automobile population grew at 0.094% per year, and the number of all motor vehicles grew at 0.49% per year. At the same time the number of buses decreased at 3.5% per year. There are now 0.55 automobiles per capita and 0.69 motor vehicles per capita. A simple projection to the year 2000 shows Illinois auto registration increasing at an average rate of 0.094% per year.

Recycling. We have only meager data on the trend in recycling at recycling centers. The total tonnage recycled at recycling centers, from a voluntary-response survey done by the Illinois Environmental Protection Agency, is 8% of Illinois' solid waste production, by weight.

SOIL

Soil erosion diminished from 1982 to 1987, as shown in Figure 1, which covers cultivated and uncultivated cropland in Illinois' 102 counties, as categorized by the Soil Conservation Service (1992). Table 1 and Figures 2 and 3 show erosion rates by county for 1982 and 1987. Figures 4 and 5 show the change and the percent change in erosion rates, respectively. The soil loss is converted to depth decrease for comparison with the actual depth of Illinois soils, assuming that soil has a specific gravity of 1.35. While soil depth is somewhat variable in definition, it is typically measured at around 10 inches, whereas the erosion rates in Figure 1 average no more than 0.03 inches per year. In Table 2, the static lifetime of the soil resource is calculated two ways:

1. Depth/erosion rate
2. Depth/(erosion rate - T),

where T is the rate of formation of new soil from bedrock. T is normally assumed to be 5 tons per acre per year (Soil Conservation Service 1992), which is

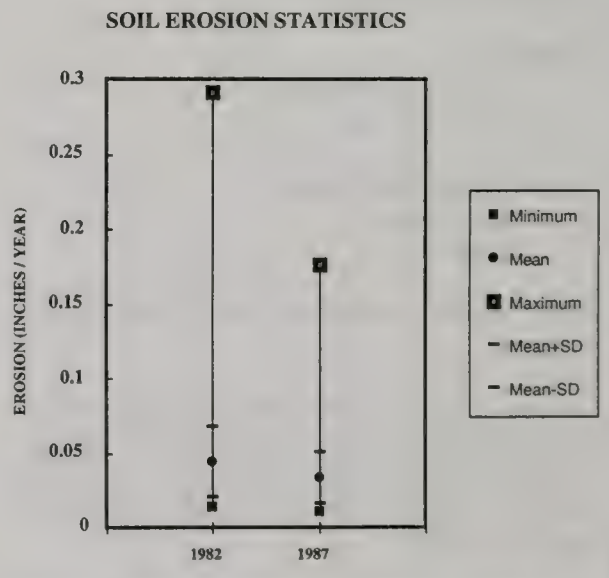

Figure 1. Statistical summary of erosion rates on cultivated and uncultivated cropland in Illinois' 102 counties, 1982 and 1987. County figures were weighted by cropland acreage. The barred range indicates values 1 standard deviation around the mean. Original data, in tons per acre per year, were converted to thickness using a specific gravity of 1.35. Source: Soil Conservation Service 1992.

Table 1. Soil erosion data by county, 1982 and 1987. Erosion figures in tons per acre per year were converted to inches per year using a soil specific gravity of 1.35. CU and UC indicate cultivated and uncultivated cropland, respectively. Source: Soil Conservation Service 1992.

COUNTY	ACRES	1982 CU + UC (THOUSAND ACRES)	1982 CU + UC EROSION (IN/ YEAR)	1982 FOREST (THOUSAND ACRES)	1982 FOREST EROSION (IN/ YEAR)	1982 PASTURE (THOUSAND ACRES)	1982 PASTURE EROSION (IN/ YEAR)	1982 COUNTY EROSION TOTAL (INCHES/ YEAR)
		A	B	C	D	E	F	G
ADAMS	551303.4	367.4	0.052	44.7	0.047	88.2	0.014	0.045
ALEXANDER	159674.52	88.9	0.037	30.3	0.010	0	0.000	0.030
BOND	242342.9	183.2	0.046	32.7	0.101	8.1	0.054	0.055
BOONE	179085.2	138.7	0.025	0	0.000	24.7	0.005	0.022
BROWN	194458.61	101.5	0.054	51.2	0.012	34.4	0.037	0.039
BUREAU	554217.99	426	0.057	48.2	0.022	42.6	0.001	0.049
CALHOUN	178539.65	50.8	0.292	69.3	0.288	3.7	0.018	0.282
CARROLL	295992.12	210.9	0.065	19	0.049	24.7	0.011	0.059
CASS	243333.89	154	0.050	67.4	0.009	4.4	0.005	0.037
CHAMPAIGN	632145.79	573.7	0.024	3.8	0.001	1.4	0.000	0.023
CHRISTIAN	452858.5	416.4	0.029	3.4	0.007	6.1	0.015	0.029
CLARK	318810.76	197.6	0.029	74	0.005	28.6	0.005	0.021
CLAY	297120.51	166.9	0.030	66	0.000	49.4	0.001	0.018
CLINTON	318628.41	227.4	0.026	22	0.001	7.9	0.007	0.023
COLES	323116.63	225.6	0.039	70.4	0.012	0.9	0.019	0.033
COOK	607230.9	35.7	0.065	31.6	0.003	22.6	0.005	0.028
CRAWFORD	281724.11	143.2	0.052	88.9	0.002	34.4	0.003	0.029
CUMBERLAND	219488.75	154.1	0.029	50	0.001	4.9	0.046	0.023
DEKALB	402704.39	357	0.044	0	0.000	17.9	0.005	0.043
DEWITT	256452.03	230	0.044	0	0.000	8	0.007	0.042
DOUGLAS	264211.43	246.5	0.022	1.4	0.000	1.3	0.027	0.022
DUPAGE	213475.24	37	0.049	8	0.001	10.2	0.000	0.033
EDGAR	393880.84	342.5	0.033	7.8	0.017	28.6	0 010	0.031
EDWARDS	140954.75	103.7	0.053	12.2	0.003	18.9	0.010	0.042
EFFINGHAM	303955.8	227.4	0.024	8.3	0.001	46.3	0.006	0.020
FAYETTE	459256.89	322.5	0.018	37.8	0.057	67.5	0.022	0.022
FORD	308094.19	293.3	0.025	0	0.000	0	0.000	0.025
FRANKLIN	273307.82	165.4	0.081	43	0.003	18.4	0.006	0.060
FULTON	559506.98	349.9	0.045	134.5	0.008	39.6	0.011	0.033
GALLATIN	207042.79	150.4	0.039	18.6	0.001	17.5	0.056	0.037
GREENE	346250.12	289	0.053	10.6	0.046	8.9	0.018	0.052
GRUNDY	272949.32	223.1	0.014	0	0.000	21.7	0.000	0.012
HAMILTON	275993.56	185.2	0.036	27.5	0.001	54	0.005	0.026
HANCOCK	514490.98	325.7	0.050	50	0.001	107.4	0.011	0.037
HARDIN	112270.69	21.3	0.123	37.2	0.005	27.2	0.005	0.034
HENDERSON	250351.04	136.8	0.046	23.6	0.031	65.2	0.007	0.033
HARDIN	112270.69	21.3	0.123	37.2	0.005	27.2	0.005	0.034
HENDERSON	250351.04	136.8	0.046	23.6	0.031	65.2	0.007	0.033
HENRY	523024.15	424.7	0.076	46.2	0.037	15.2	0.001	0.070
IROQUOIS	708878	663.2	0.022	0	0.000	7	0.001	0.021
JACKSON	382249.86	182.8	0.056	80.8	0.007	35.7	0.016	0.038
JASPER	315429.42	198.7	0.035	85.9	0.000	11.4	0.005	0.023
JEFFERSON	369633.89	178	0.069	54.6	0.003	90	0.015	0.042
JERSEY	238927.05	159.2	0.068	25.7	0.030	32.2	0.039	0.059
JODAVIESS	392150.23	218.1	0.086	69.5	0.027	56.7	0.011	0.062
JOHNSON	220833.05	28.1	0.090	85	0.008	79.6	0.042	0.034
KANE	332582.39	243.7	0.039	3.5	0.001	6.5	0.003	0.037
KANKAKEE	431754.42	319.1	0.027	32.3	0.001	32.8	0.001	0.022
KENDALL	204431.34	154.3	0.027	0.9	0.000	30.8	0.000	0.023
KNOX	455909.34	293.2	0.040	26.3	0.001	100.4	0.045	0.039

Table 1 (continued)

		A	B	C	D	E	F	G
LAKE	298141.16	73.6	0.055	17.4	0.001	24.7	0.001	0.035
LASALLE	727984.9	561.7	0.031	24.2	0.004	78.9	0.001	0.026
LAWRENCE	236144.28	204.9	0.037	7.2	0.000	11.6	0.004	0.034
LEE	462209.31	318.6	0.036	74.8	0.007	38.4	0.007	0.028
LIVINGSTON	662753.32	613.1	0.022	0	0.000	9.5	0.003	0.022
LOGAN	391872.9	370.5	0.027	0	0.000	1.9	0.002	0.027
MCDONOUGH	373708.68	257.2	0.037	28.8	0.012	71.5	0.006	0.028
MCHENRY	387904.88	228.5	0.035	30.3	0.079	56.7	0.003	0.034
MCLEAN	751386.77	684.4	0.050	0	0.000	21.3	0.003	0.048
MACON	370937.76	320.3	0.039	0	0.000	0	0.000	0.039
MACOUPIN	549074.44	356.5	0.039	70	0.009	87.7	0.027	0.033
MADISON	468480.01	260.2	0.074	79.8	0.004	30.3	0.042	0.057
MARION	364631.58	164.1	0.047	110.1	0.004	59	0.007	0.026
MARSHALL	252808.34	182	0.060	10.5	0.004	37.7	0.004	0.048
MASON	355729.24	293.5	0.021	25.4	0.039	5.2	0.002	0.022
MASSAC	151798.07	64.2	0.061	29.3	0.022	44.9	0.017	0.039
MENARD	199601.01	143.8	0.038	16.8	0.160	30.5	0.033	0.048
MERCER	359574.34	256.1	0.093	7.3	0.005	71.8	0.103	0.094
MONROE	251430.62	142.3	0.098	87.9	0.062	2.4	0.067	0.084
MONTGOMERY	449233.9	296.5	0.027	60.5	0.007	61.4	0.007	0.021
MORGAN	362701.04	290.7	0.106	8.9	0.017	38.1	0.025	0.095
MOULTRIE	217812.79	181.7	0.023	3.9	0.002	5.1	0.013	0.022
PERRY	283094.81	132.4	0.095	45.5	0.003	75.1	0.005	0.052
PIATT	278155.17	263.2	0.027	0	0.000	1.2	0.001	0.027
PIKE	535799.98	382.9	0.065	78.3	0.013	36.3	0.019	0.053
POPE	236020.89	42.8	0.068	71.6	0.002	30.7	0.016	0.024
PULASKI	127330.62	87	0.124	27.2	0.010	8.2	0.004	0.091
PUTNAM	109133.46	47.2	0.072	21.2	0.034	25.1	0.007	0.046
RANDOLPH	373761.41	233	0.069	46.9	0.014	63.8	0.025	0.053
RICHLAND	229130.61	185	0.057	3.4	0.001	27.7	0.015	0.051
ROCKISLAND	284887.47	185	0.040	9.3	0.003	12.6	0.006	0.036
ST.CLAIR	426654.2	231.4	0.063	61.6	0.001	40.5	0.032	0.048
SALINE	245037.97	110.8	0.056	57.6	0.003	32.6	0.012	0.033
SANGAMON	555423.3	404.8	0.044	27.3	0.016	60.5	0.008	0.038
SCHUYLER	279498.61	192.4	0.042	26.8	0.009	47.2	0.069	0.044
SCOTT	159637.32	115.8	0.050	15.2	0.001	21	0.014	0.040
SHELBY	486372.58	364.9	0.039	32.3	0.001	46.5	0.003	0.033
STARK	182825.59	165.8	0.069	0	0.000	8.2	0.006	0.066
STEPHENSON	358412.29	307.3	0.041	5.7	0.010	17.8	0.003	0.039
TAZEWELL	416803.44	336.7	0.034	7.9	0.025	16.3	0.025	0.033
UNION	267355.37	46	0.180	137.1	0.012	29.4	0.019	0.049
VERMILION	570284.93	513.9	0.031	9.1	0.018	10.1	0.018	0.030
WABASH	143242.57	120.1	0.038	12.9	0.001	2.5	0.015	0.034
WARREN	344530.17	242.5	0.037	22.6	0.006	63.3	0.009	0.029
WASHINGTON	356935.6	277	0.035	57.6	0.017	4.7	0.018	0.032
WAYNE	452959.55	340.9	0.022	75.8	0.000	13.6	0.003	0.017
WHITE	316140.95	173	0.035	21.9	0.001	106.3	0.010	0.023
WHITESIDE	442417.72	385.2	0.040	3.1	0.002	4.3	0.161	0.041
WILL	538380.06	338.7	0.027	4.8	0.001	33.7	0.005	0.025
WILLIAMSON	281293.8	87.8	0.126	55	0.001	56.5	0.016	0.060
WINNEBAGO	329726.59	239.9	0.032	6.7	0.001	6.4	0.002	0.030
WOODFORD	336767.88	283.8	0.036	23.3	0.003	3.9	0.004	0.033
SUM:	35,657,703	24,728		3,430		3,158		
WEIGHTED MEAN:			0.044		0.019		0.017	0.039
STD. DEVIATION:			0.024		0.044		0.020	0.023

Table 1 (continued)

COUNTY	ACRES	1987 CU + UC (THOUSAND ACRES)	1987 CU + UC EROSION (IN/ YEAR)	1987 FOREST (THOUSAND ACRES)	1987 FOREST EROSION (IN/ YEAR)	1987 PASTURE (THOUSAND ACRES)	1987 PASTURE EROSION (IN/ YEAR)	1987 COUNTY EROSION TOTAL (INCHES/ YEAR)	%CH/YR IN LAND USE CU + UC AVER OVER 5 YEARS
		H	I	J	K	L	M	N	O
ADAMS	551303.4	328.5	0.037	44.4	0.007	126.1	0.008	0.027	-2.12
ALEXANDER	159674.52	88.8	0.031	30.3	0.010	0	0.000	0.025	-0 02
BOND	242342.9	187.1	0.045	31	0.106	5.9	0.072	0.054	0.43
BOONE	179085.2	125.5	0.025	0	0.000	37.4	0.005	0.020	-1.90
BROWN	194458.61	89.3	0.046	51.1	0.007	46.4	0.027	0.031	-2.40
BUREAU	554217.99	426.2	0.048	48.1	0.022	42.4	0.001	0.042	0.01
CALHOUN	178539.65	48.8	0.177	69	0.113	2.2	0.017	0.137	-0.79
CARROLL	295992.12	206.6	0.047	18.9	0.048	28.8	0.009	0.043	-0.41
CASS	243333.89	155.4	0.040	67.4	0.009	2.9	0.004	0.031	0.18
CHAMPAIGN	632145.79	574.8	0.014	3.4	0.001	1.4	0.000	0.014	0.04
CHRISTIAN	452858.5	416.3	0.021	3.4	0.007	5.9	0.014	0.021	0.00
CLARK	318810.76	199.4	0.023	74.1	0.005	27.1	0.005	0.017	0 18
CLAY	297120.51	198.7	0.024	65.9	0.000	17.6	0.001	0.017	3 81
CLINTON	318628.41	234.6	0.028	21.5	0.001	0	0.000	0.026	0 63
COLES	323116.63	225.9	0.034	70.1	0.012	0.6	0.018	0.029	0 03
COOK	607230.9	28.2	0.070	30.6	0.001	22.5	0.001	0.025	-4 20
CRAWFORD	281724.11	161.2	0.041	79.5	0.003	25.9	0.002	0.026	2.51
CUMBERLAND	219488.75	153.1	0.024	50.6	0.001	5.5	0.018	0.018	-0 13
DEKALB	402704.39	370.2	0.037	0	0.000	2.9	0.028	0.037	0.74
DEWITT	256452.03	236.5	0.038	0	0.000	1.6	0.054	0.038	0.57
DOUGLAS	264211.43	246.9	0.022	1.2	0.000	1.2	0.027	0.022	0.03
DUPAGE	213475.24	30.3	0.040	7.6	0.001	10.2	0.000	0.026	-3.62
EDGAR	393880.84	344.6	0.018	11	0.014	23	0.012	0.018	0.12
EDWARDS	140954.75	101.4	0.042	12	0.003	21.1	0.004	0.032	-0.44
EFFINGHAM	303955.8	244.8	0.015	8.5	0.005	28.6	0.010	0.014	1.53
FAYETTE	459256.89	348.6	0.022	37.5	0.057	41.1	0.012	0.024	1.62
FORD	308094.19	293.4	0.024	0	0.000	0	0.000	0.024	0 01
FRANKLIN	273307.82	163.6	0.055	45.7	0.008	10.1	0.007	0.043	-0.22
FULTON	559506.98	351.9	0.044	127.3	0.005	46.7	0.010	0.031	0.11
GALLATIN	207042.79	151.6	0.033	17,8	0.001	16.7	0.059	0.032	0.16
GREENE	346250.12	305.3	0.037	10.5	0.047	15.2	0.027	0.036	1 13
GRUNDY	272949.32	222.6	0.013	0	0.000	21.6	0.000	0.012	-0.04
HAMILTON	275993.56	202.6	0.029	28.4	0.001	35.3	0.007	0.023	1 88
HANCOCK	514490.98	356.8	0.035	74.3	0.003	51.5	0.033	0.030	1.91
HARDIN	112270.69	20.6	0.144	37	0.025	27.7	0.005	0.047	-0 66
HENDERSON	250351.04	136.8	0.031	24,8	0.009	63.9	0.006	0.021	0 00
HENRY	523024.15	424.6	0.052	51	0.033	9.9	0.000	0 049	0 00
IROQUOIS	708878	665.7	0.011	0	0.000	3.9	0.001	0.011	0.08
JACKSON	382249.86	205.8	0.050	82.2	0.007	10.2	0.039	0 038	2 52
JASPER	315429.42	200	0.029	85.8	0.000	9.6	0.005	0.020	0.13
JEFFERSON	369633.89	175.8	0.069	54	0.003	92.1	0.014	0 042	-0.25
JERSEY	238927.05	159.5	0.051	25.2	0.031	31.5	0.028	0 045	0 04
JODAVIESS	392150.23	219.6	0.052	69.3	0.032	55	0.011	0 042	0 14
JOHNSON	220833.05	27.1	0.080	84.4	0.008	80.5	0.042	0.033	-0 71
KANE	332582.39	238.5	0.032	2.5	0.000	6.1	0.003	0.031	-0 43
KANKAKEE	431754.42	320.2	0.016	31.4	0.001	31.4	0.001	0.013	0.07
KENDALL	204431.34	155	0.027	0.8	0.000	29.7	0.000	0 023	0 09
KNOX	455909.34	301.8	0.035	30.8	0.001	88.4	0.016	0.029	0 59
LAKE	298141.16	74.5	0.043	15.4	0.001	21.8	0.001	0 029	0 24
LASALLE	727984.9	560.7	0.026	24	0.004	78.7	0.001	0 022	-0 04

Table 1 (continued)

		H	I	J	K	L	M	N	O
LAWRENCE	236144.28	208	0.033	7	0.000	8.7	0.003	0.030	0.30
LEE	462209.31	356.4	0.026	74.1	0.007	0	0.000	0.023	2.37
LIVINGSTON	662753.32	614.1	0.018	0	0.000	8.1	0.001	0.017	0.03
LOGAN	391872.9	371.2	0.012	0	0.000	1.7	0.001	0.012	0.04
MCDONOUGH	373708.68	257.2	0.033	28.8	0.012	71.1	0.006	0.026	0.00
MCHENRY	387904.88	207.8	0.037	30.3	0.079	72	0.003	0.033	-1.81
MCLEAN	751386.77	702	0.026	3	0.001	0	0.000	0.026	0.51
MACON	370937.78	320.7	0.028	0	0.000	0	0.000	0.028	0.02
MACOUPIN	549074.44	378.6	0.039	67	0.010	67.7	0.031	0.034	1.24
MADISON	468480.01	257.2	0.060	78.8	0.004	30.2	0.041	0.046	-0.23
MARION	364631.58	200.1	0.039	109.5	0.004	22.2	0.007	0.025	4.39
MARSHALL	252808.34	188.6	0.041	10.2	0.004	31.1	0.002	0.034	0.73
MASON	355729.24	292.6	0.020	25.4	0.039	6.7	0.001	0.021	-0.06
MASSAC	151798.07	69.3	0.054	29.2	0.008	39.8	0.015	0.033	1.59
MENARD	199601.01	145.7	0.028	22	0.123	23	0.043	0.041	0.26
MERCER	359574.34	258.3	0.068	17.1	0.007	59.7	0.097	0.070	0.17
MONROE	251430.62	143.1	0.084	87.3	0.063	2.3	0.065	0.076	0.11
MONTGOMERY	449233.9	334.2	0.022	59.9	0.007	24.4	0.018	0.020	2.54
MORGAN	362701.04	315.3	0.081	8.7	0.015	13.5	0.037	0.077	1.69
MOULTRIE	217812.79	181.9	0.014	3.8	0.001	5	0.002	0.013	0.02
OGLE	484562.7	424.4	0.037	10.1	0.013	8.6	0.001	0.036	0.53
PEORIA	399181.89	276.9	0.042	42.7	0.001	14.6	0.015	0.035	-0.28
PERRY	283094.81	135.6	0.063	42	0.003	65.7	0.005	0.037	0.48
PIATT	278155.17	263.5	0.022	0	0.000	1.2	0.001	0.022	0.02
PIKE	535799.98	388.3	0.050	77.2	0.014	31.8	0.005	0.041	0.28
POPE	236020.89	38.5	0.069	69.9	0.012	34	0.023	0.030	-2.01
PULASKI	127330.62	88.9	0.093	27.1	0.010	6.3	0.003	0.070	0.44
PUTNAM	109133.46	47.2	0.040	22.7	0.007	23.5	0.001	0.022	0.00
RANDOLPH	373761.41	228.7	0.061	47.6	0.016	67.1	0.009	0.044	-0.37
RICHLAND	229130.61	188.9	0.041	6.6	0.002	20.3	0.020	0.038	0.42
ROCKISLAND	284887.47	172.7	0.029	9.7	0.003	24.8	0.003	0.024	-1.33
ST.CLAIR	426654.2	239	0.057	60.3	0.001	40.3	0.033	0.045	0.66
SALINE	245037.97	118.6	0.039	58.7	0.002	23.3	0.016	0.026	1.41
SANGAMON	555423.3	421.6	0.041	26.8	0.008	43.6	0.013	0.037	0.83
SCHUYLER	279498.61	207.7	0.040	26.8	0.009	31.8	0.014	0.034	1.59
SCOTT	159637.32	116	0.049	15.1	0.001	21	0.012	0.039	0.03
SHELBY	486372.58	362.7	0.030	32.3	0.001	48.8	0.003	0.025	-0.12
STARK	182825.59	165.4	0.049	0	0.000	8.6	0.003	0.047	-0.05
STEPHENSON	358412.29	307	0.020	5.3	0.010	17.6	0.003	0.019	-0.02
TAZEWELL	416803.44	336.6	0.029	7.7	0.021	16.2	0.025	0.028	-0.01
UNION	267355.37	47.3	0.101	139.2	0.012	25.5	0.022	0.033	0.57
VERMILION	570284.93	514.7	0.016	8.9	0.018	8.8	0.022	0.018	0.03
WABASH	143242.57	120.8	0.029	12.8	0.001	1.8	0.008	0.026	0.12
WARREN	344530.17	261.1	0.023	22.3	0.006	44	0.012	0.020	1.53
WASHINGTON	356935.6	277	0.027	57.5	0.017	4.6	0.018	0.026	0.00
WAYNE	452959.55	332.7	0.020	75.3	0.000	21.2	0.003	0.016	-0.48
WHITE	316140.95	197.8	0.029	33	0.003	70.4	0.006	0.021	2.87
WHITESIDE	442417.72	387	0.030	2.2	0.001	3.2	0.129	0.031	0.09
WILL	538380.06	334	0.020	3.2	0.004	33.7	0.005	0.018	-0.28
WILLIAMSON	281293.8	89.1	0.078	53.6	0.001	65.7	0.037	0.045	0.34
WINNEBAGO	329726.59	239.1	0.032	4.9	0.002	4.1	0.003	0.031	-0.07
WOODFORD	335767.88	284.3	0.022	23.2	0.003	3.9	0.004	0.020	0.04
SUM:	35,657,703	25,121		3,447		2,689			
WEIGHTED MEAN:			0.034		0.015		0.015	0.030	
STD. DEVIATION:			0.017		0.024		0.018	0.015	

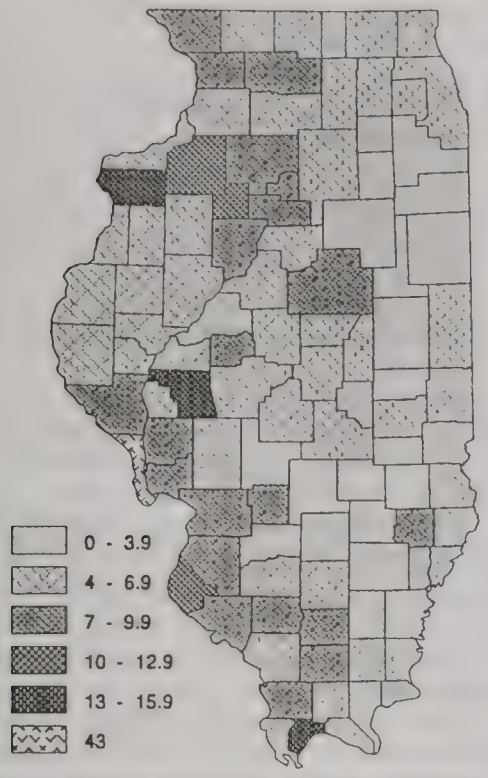

Figure 2. Erosion by county, 1982 (values given in tons per acre per year).

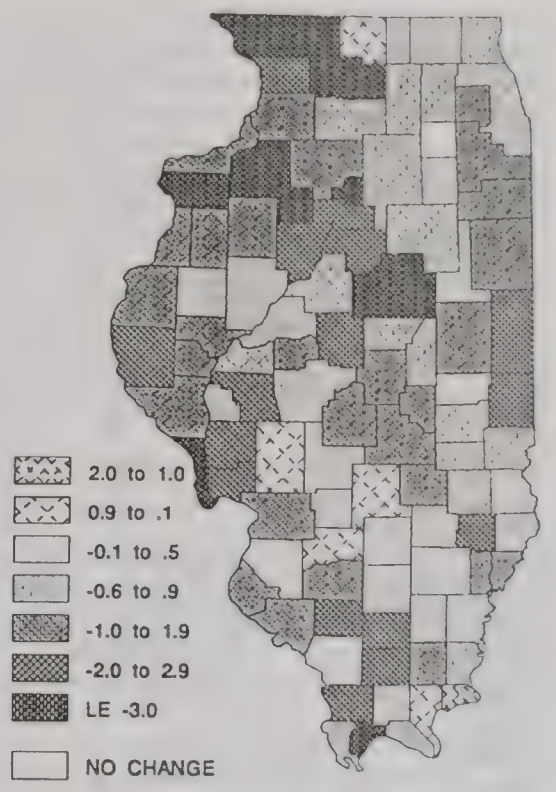

Figure 4. Change in erosion, 1982–1987 (values given in tons per acre per year).

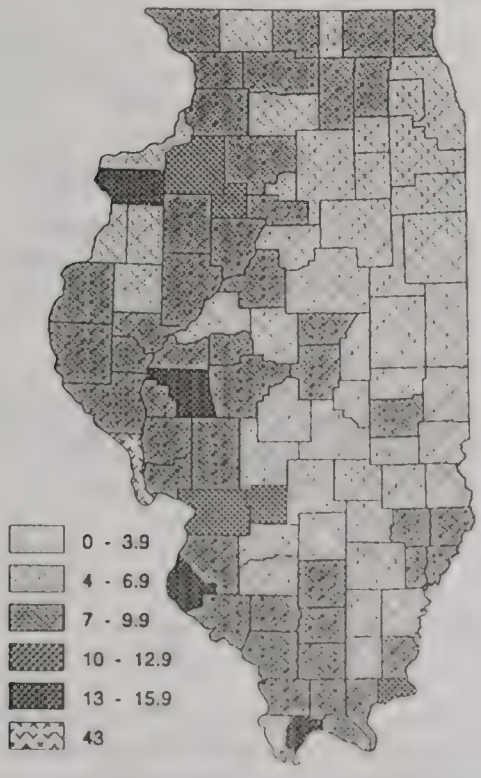

Figure 3. Erosion by county, 1987 (values given in tons per acre per year).

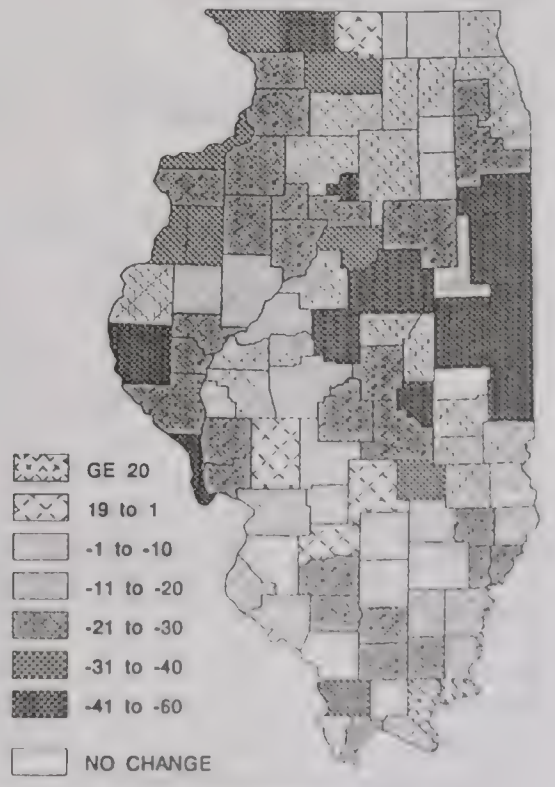

Figure 5. Percent change in erosion, 1982–1987.

Table 2. Soil depths and static lifetimes for 42 counties using A-horizon thickness. A-horizon depths are averages from the maximum and minimum A-horizon depths. Soil is assumed to have a specific gravity of 1.35. An asterisk in a static lifetime column indicates that soil is accumulating faster than it erodes.

County name	Erosion rate 1987 (inches/yr)	Soil depth (inches) A-horizon cty surveys	Static lifetime in years A-horizon with T	Static lifetime in years A-horizon without T
Adams	0.027	5.87	*	221
Alexander	0.025	4.53	*	179
Bond	0.054	4.06	192	75
Broone	0.020	6.20	*	307
Brown	0.031	3.35	*	109
Calhoun	0.137	3.21	31	23
Carrol	0.043	8.00	814	187
Champaign	0.014	7.50	*	551
Clark	0.017	7.83	*	456
Dekalb	0.037	6.70	1616	181
Douglas	0.022	7.23	*	327
DuPage	0.026	4.54	*	178
Gallatin	0.032	5.79	*	182
Greene	0.036	7.29	2116	200
Grundy	0.012	7.44	*	625
Hamilton	0.023	3.87	*	169
Hardin	0.047	3.97	279	84
Henry	0.049	6.69	413	136
Iroquois	0.011	7.25	*	657
Jackson	0.038	5.00	1035	132
Jersey	0.045	7.45	609	165
Kane	0.031	6.49	*	210
Kankakee	0.013	7.55	*	572
La Salle	0.022	7.12	*	319
Lee	0.023	6.50	*	284
Madison	0.046	4.36	325	94
Massac	0.033	4.99	*	152
Mercer	0.070	6.04	164	86
Morgan	0.077	6.32	142	82
Ogle	0.036	7.78	2631	217
Perry	0.037	2.97	821	81
Pope	0.030	3.57	*	119
Pulaski	0.070	5.19	141	74
Saline	0.026	5.48	*	214
Sangamon	0.037	7.86	2051	214
Scott	0.039	5.42	877	139
Stephenson	0.019	7.57	*	409
St. Clair	0.048	6.15	535	138
Union	0.033	3.94	*	120
Wabash	0.026	6.42	*	243
Winnebago	0.031	6.34	*	205

Source: Soil Conservation Service 1992.

equivalent to 0.033 inches per year. We assume T is the same for all locations.

In Table 2, soil depth is that to the "A-horizon," which corresponds well with the concept of organic soil that is capable of supporting agricultural production without extensive fertilization. Strictly speaking, this is richer than, and therefore not equivalent to, the soil being formed by breakdown of bedrock. Thus, calculating static lifetime with T reflects an optimistic view of soil lifetime, and calculating without T reflects a pessimistic view.

In general, static lifetimes are hundreds of years. On the time scale of human generations, soil erosion is therefore not a pressing issue *from the standpoint of depletion.* Soil erosion's effect on stream quality, river siltation, blockage of navigation channels, etc., can be a pressing issue, as covered elsewhere in this volume. Further, as shown in Figure 1, the erosion rate decreased from 1982 to 1987. In contrast, in some counties a more important influence on the soil "stock" is changing land use patterns. Columns A, C, and E for 1982 and Columns H, J and L for 1987 of Table 1 show that area changes are approximately 10 times as large (on a fractional basis) as depth changes from erosion. For example, from 1982 to 1987 the statewide acreage of cultivated and uncultivated cropland actually increased approximately 1.5% (while areas of pasture decreased). Cropland area changes must, of course, be evaluated relative to changes in land for other environmentally desirable uses such as forests and wetlands.

Table 3 shows the average annual depth and area changes for several counties during 1982–1987, using the rate of soil loss corrected or uncorrected for T. These are chosen as examples because the fractional area changes are relatively large.

Table 3. Annual change in soil depth and in cropland area for four selected Illinois counties, 1982–1987, based on A-horizon soil depth.

County	Change in soil depth per year with T	Change in soil depth per year without T	Change in cropland area per year
Adams	-0.194%	-0.756%	-2.1%
Brown	-0.516%	-1.501%	-2.1%
Lee	0.031%	-0.477%	2.4%
Jackson	-0.404%	-1.064%	2.5%

FORESTS

Forests are a potentially renewable resource that benefits the Illinois economy and environment. Beyond income from timber harvests, Illinois forests create income from tourism at county and state forests and parks and national forests. Forests help clean the air and water, they help stabilize soil and water, and they provide habitat for Illinois' diverse wildlife.

Before settlement, forests occupied 13.8 million (39%) of Illinois' 35.6 million acres of land (Figure 6). By 1962 there were only 3.8 million acres of forested land (11% of Illinois). From 1962 to 1985 this increased to 4.26 million acres (12% of Illinois).

Commercial forested land is classified as forested area that produces or is capable of producing timber for industrial harvest. In 1962, Illinois had 3.7 million acres of commercial forested land (97% of total forested land) (Figure 7). By 1985, the amount of commercial forested land had increased to 4 million acres (93% of total forested land).

In 1962 annual growth in commercial forested areas exceeded than the amount harvested. In 1985, however, this was reversed: more timber was harvested than was added by new growth (Figure 8).

The change in forest management techniques is shown by the change in forest biomass reserves. In 1962, Illinois had a net increase in commercial forest biomass of 1.45% per year (Figure 9). In 1985, Illinois had a net loss of commercial forest biomass reserves of 2.44% per year.

ETHANOL FROM GRAIN

The amount of ethanol produced in Illinois from grain has increased steadily since the late 1970s (Figure 10). Today's in-state production of 1 billion gallons uses 400 million bushels of corn, which is 31% of the state's corn production.

Ethanol from Illinois is used as a gasoline additive in many states. If it all were used in-state, it would be equivalent to one-sixth of Illinois' liquid road fuel consumption on a volume basis.

Ethanol, being made from a crop, is classified as renewable energy, but there is continued controversy about how justified this title is. The question is one of "net energy," recognizing that corn production and the

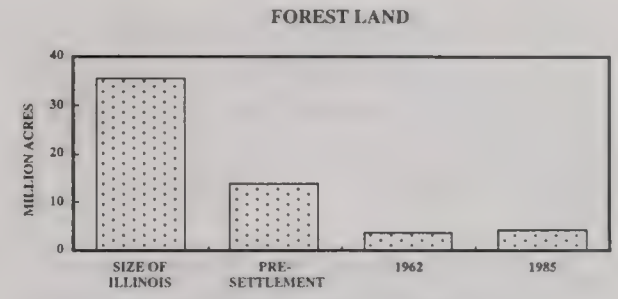

Figure 6. Forested land in Illinois. Even in pre-settlement times, only 39% of Illinois was forested. Today 12% is forested. Sources: Essex and Gansner 1965, Hann 1987, Iverson et al. 1985.

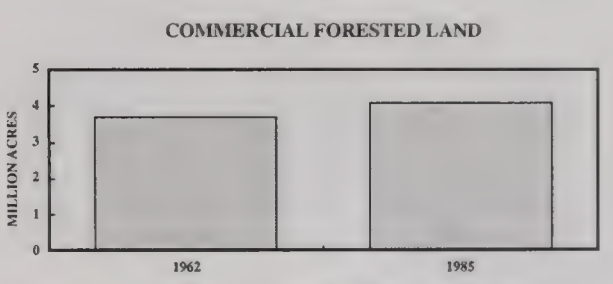

Figure 7. Commerical forested land, 1962 and 1985. Sources: Essex and Gansner 1965, Hann 1987, Iverson et al. 1985.

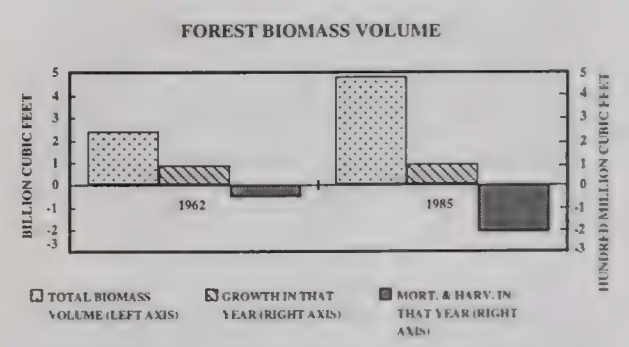

Figure 8. Biomass volume, yearly growth, and yearly mortality plus harvest for 1962 and 1985. In 1962 growth exceeded mortality plus harvest. In 1985 the opposite was true. Sources: Essex and Gansner 1965, Hann 1987, Iverson et al. 1985.

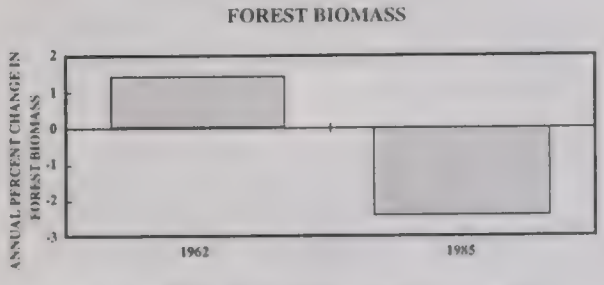

Figure 9. Net change in forest biomass, 1962 and 1985. Sources: Essex and Gansner 1965, Hann 1987, Iverson et al. 1985.

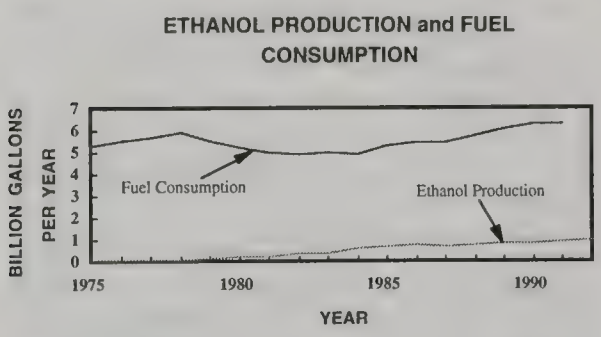

Figure 10. Illinois ethanol production, 1975–1992. Source: Illinois Corn Growers Association.

conversion of corn to ethanol both require large fossil fuel energy inputs. The answer depends on what data are used, what conceptual boundaries are chosen, and several other issues. One research group found ethanol close to producing zero net energy (Chambers et al. 1979). Another found that positive net energy results (Goering 1992).

COAL

Coal use and the quality of the environment are intricately linked. For example, coal use in Illinois creates 31% of the energy-related CO_2 and approximately nine-tenths of the SO_2 (USEPA 1991). Illinois has about 10% of the nation's coal reserves and today accounts for 5% of coal production in the United States.

The history of coal production in Illinois follows closely the history of coal production in the United States. Production increased dramatically up through World War I and then fell off during the economic depression of the 1930s (Figure 11). During World War II the demand for coal surged, and by 1944 Illinois produced 70 million tons per year. Illinois, as well as the nation, felt the slump in the coal market in the 1950s. Production increased in the 1960s and 1970s as the demand for electricity increased. Production of coal has remained fairly constant since 1970 except for a drop in the early 1980s.

Consumption of coal in Illinois reached a peak in 1969 of 45 million tons. Since 1969 the consumption of coal has varied from year to year but has generally shown a downward trend. From 1969 to 1990, consumption declined 28%, to 32 million tons per year.

Reserves for the state are defined as coal that has high development value, which depends on factors such as the location, depth, extent, and seam thickness. Coal reserves are difficult to determine; the starting figure for this report is 50 billion tons, which was established in 1976 (Illinois Department of Energy 1982). However, this is likely an overestimate. Accounting for mining and cleaning losses, difficulties with thin seams, and other factors, a more realistic value is between 4 and 20 billion tons (Damberger, 1993, personal communication). Hence we use 20 billion tons, acknowledging its uncertainty. This is equivalent to 1800 tons per Illinois citizen. If spread out evenly over the entire state, it would form a layer 2 inches thick. If it were burned, the CO_2 produced would represent 2.8% of the present atmospheric CO_2.

Illinois coal reserves greatly exceed annual consumption. The static lifetime has increased from 555 years in 1960 to 615 years in 1990 (Figure 12). Given the uncertainty of reserves figures, the fluctuations in this

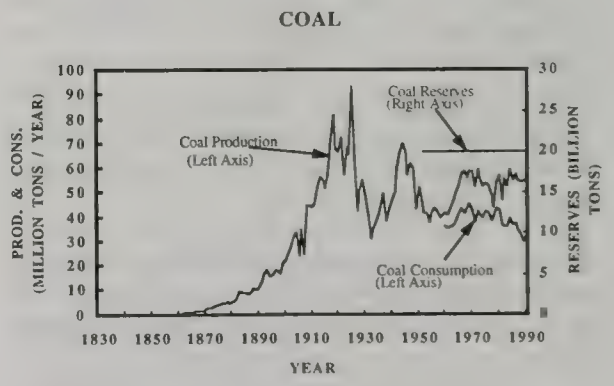

Figure 11. Production, consumption, and reserves of coal in Illinois. Note that reserves are in billions of tons, while production and consumption are in millions of tons per year. Sources: Cady 1954, Hopkins and Simon 1974, Illinois Department of Energy 1982, Tweworgy and Bargh 1982, Damberger 1993.

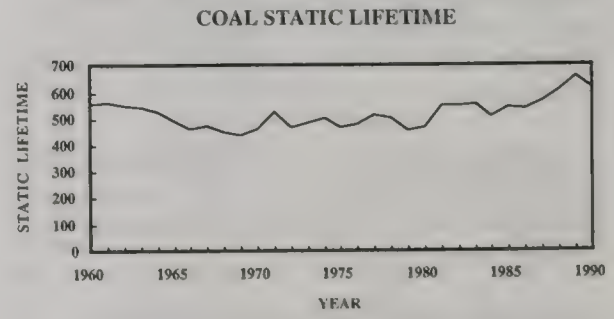

Figure 12. Static lifetime of Illinois coal reserves. Static lifetime is reserves divided by current annual consumption.

Table 4. Static lifetime of coal, oil, and natural gas for industrialized countries, the world, and Illinois.

	Europe, North America, and Japan	World	Illinois
Coal	240 years	230 years	~600 years
Oil	12 years	30 years	~10 months
Natural gas	15 years	60 years	<1 month

Sources: 1993 Information Please Almanac, World Resources Institute 1993, and this report.

trend are not significant. The overall picture is that Illinois has enough coal for hundreds of years at current consumption levels. In Table 4, we compare static lifetime for Illinois, the developed world, and the entire world. All are measured in hundreds of years.

OIL

Petroleum provides many benefits to the people of Illinois, mainly through transportation and mechanization of agriculture. It has had a large impact on the environment as well. Oil consumption is responsible for 45% of Illinois' energy-related CO_2 releases.

Crude oil production in Illinois has been recorded since 1905. In 1908, production was about 34 million barrels per year (Figure 13). After 1908, production dropped until 1938, when the state found new sources. Oil production peaked in 1940 at 148 million barrels. After 1940 production dropped until 1950, when secondary recovery methods were utilized. After a small increase, the production of crude oil dropped steadily with only a small increase in the mid 1980s.

Oil reserves are defined as crude oil that is economically recoverable. Crude oil reserves shot up in the 1950s when secondary recovery methods were introduced (Figure 13). After a peak in 1960 reserves continued to drop to a level of 143 million barrels in 1988. State crude oil consumption increased from 1957 to a peak of 265 million barrels in 1978 (Figure 13). Consumption dropped until 1985 and then began to increase again.

Static lifetime of crude oil reserves dropped steadily from 1960 until the mid-1970s and has remained approximately constant at 0.8 years (Figure 14). Since 1970, Illinois has consumed more oil each year than it has in the ground. This is accomplished by heavy importation of oil.

Illinois' static oil lifetime is 0.8 years, compared 12 and 30 years for the industrialized countries as a whole and for the entire world, respectively (Table 4).

NATURAL GAS

Natural gas, like crude oil, has an important role in Illinois' economy and environment. Though natural gas is the least carbon-intensive of the fossil fuels, it creates 23% of the state's energy-related CO_2. The state of Illinois has never been an important producer of natural gas.

The production of natural gas is largely dependent on crude oil production, since it is a by-product. Production of natural gas dropped with crude oil production from 1960 to the early 1970s (Figure 15). As crude oil production stabilized in the 1970s, the amount of natural gas produced increased to a high of 1600

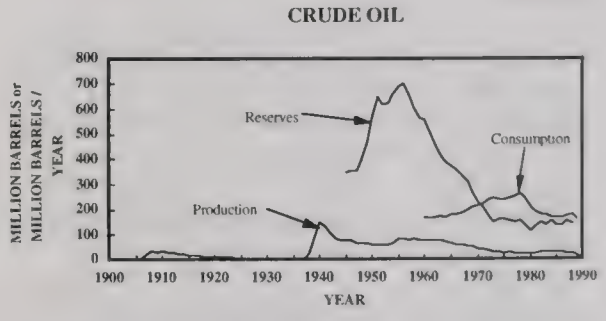

Figure 13. Production, consumption (in million barrels / year), and reserves (in million barrels) of crude oil in Illinois. Annual consumption slightly exceeds reserves. Sources: Heister and Neely 1987, Bhagwat 1992.

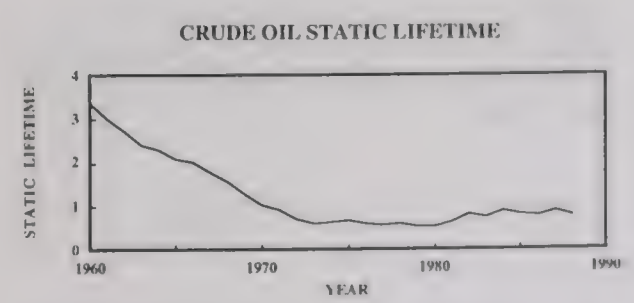

Figure 14. Static lifetime of Illinois oil reserves. Static lifetime is now roughly constant at about 1 year.

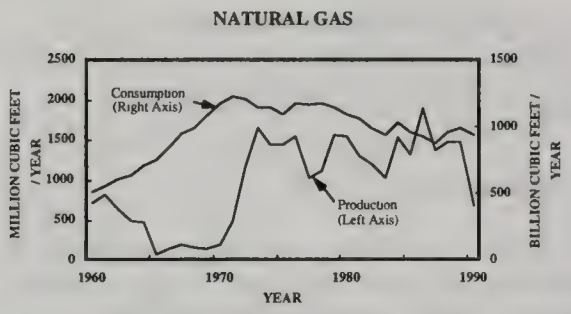

Figure 15. Consumption and production of natural gas in Illinois. Reserves are negligible. Note that production is in million cubic feet per year and consumption is in billion cubic feet per year. Sources: Heister and Neely 1987, Samson 1992, U.S. Department of Energy 1992.

million cubic feet in 1973. Production fell in the early 1980s due to the falling production of some of Illinois' major oil fields. The variation in the late 1980s is accounted for by the number of oil wells that were in operation.

Consumption of natural gas in Illinois surged during the late 1960s and early 1970s with a peak of 1229 billion cubic feet in 1972 (Figure 15). At the beginning of the 1980s the consumption of natural gas began to fall, and it reached a low in 1987 of 873 billion cubic feet. The decline of natural gas consumption during the 1980s is partially explained by warm winters.

Illinois' natural gas production is about 0.1% of its consumption, and reserves are negligible (Heister and Neely 1987). Therefore, Illinois' static lifetime for natural gas reserves is less than one month. (It is possible that there is deep gas as yet undiscovered, but that would likely be much more expensive to produce than today, and it is not included.)

Table 4 shows that, compared with Illinois' value of less than one month, the industrialized world and the whole world have gas static lifetimes of 15 and 60 years, respectively.

ENERGY/ENERGY-RELATED CO_2 RELEASES

Illinois' energy consumption peaked in the late 1970s, just before the second round of world oil price shocks (Figure 16). The reduction from that peak is almost all from reduced oil consumption (Figure 17).

Illinois' energy consumption today is approximately 80% from fossil fuels, which produce CO_2 (Figure 16). Energy use and resulting carbon dioxide release are not proportional because different fuels vary in their carbon per energy unit (Table 5).

Because coal is 1.75 times as carbon intensive as natural gas, it contributes a larger fraction of Illinois' carbon dioxide production than of energy production. Illinois' CO_2 production (237 million tons per year) is about 1% of the world's total (Lashof and Washburn 1990). For comparison, Illinois' human population is 0.2% of the world's.

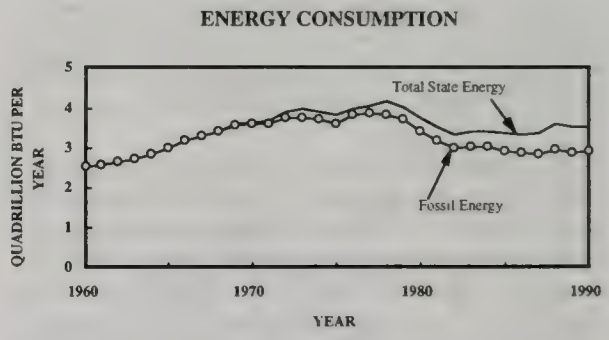

Figure 16. Total, and fossil-fuel energy consumption in Illinois, 1960–1990. The difference is hydro and nuclear electricity. Source: U.S. Department of Energy 1992.

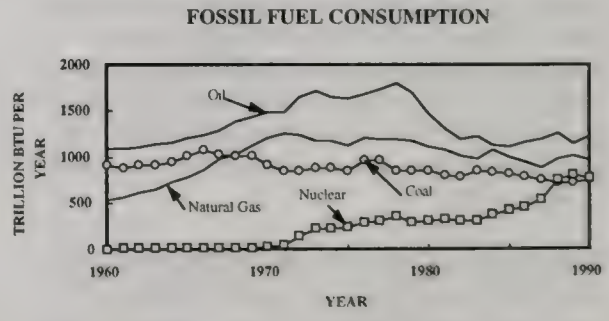

Figure 17. Fossil energy consumption in Illinois, 1960–1990. Nuclear energy consumption is included for comparison. Source: U.S. Department of Energy 1992.

Production of CO_2 in Illinois reached a peak in the late 1970s but then quickly dropped in the early 1980s with a decline in the consumption of energy, particularly petroleum (Figure 18). Energy consumption and CO_2 production stayed nearly constant through 1990. Note that CO_2 figures in this section are only related to fossil fuel use. Thus, overall state production of CO_2 is higher than portrayed in these figures.

The ratio of released CO_2 to consumed energy decreased in 1960–1990 (Figure 19). Major causes were (1) a shift from coal toward oil and natural gas, both of which are less carbon-intensive, in 1960–1980 and (2) an increase in the production of electricity from nuclear power plants, a process that produces little or no CO_2 in 1970–1990. The latter trend is evident in Figure 17. Against this overall trend, there was a small rise in the mid-1980s because the increase in the world oil price caused a disproportionate decrease in oil consumption.

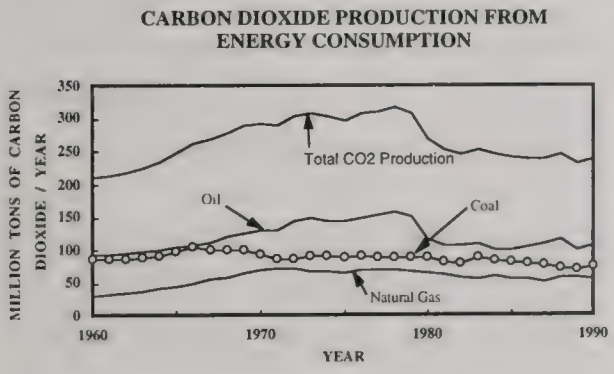

Figure 18. Energy-related carbon dioxide releases, 1960–1990. Carbon dioxide weighs 3.67 times as much as carbon. Source: U.S. Department of Energy 1992.

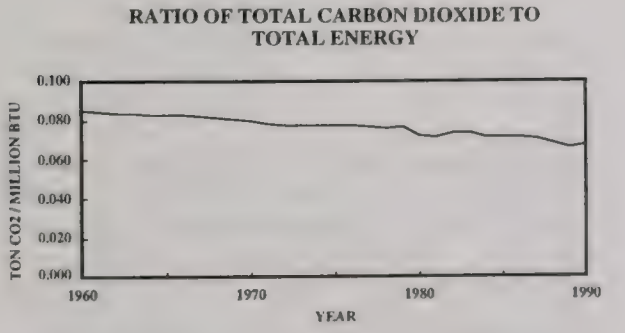

Figure 19. Ratio of energy-related CO_2 production to energy consumption in Illinois, 1960–1990. Source: U.S. Department of Energy 1992.

Figure 20 shows several simple projections (not predictions) for Illinois energy use. It is assumed that:

> Energy = (population) • (per capita gross state product) • (energy per unit of gross state product).

The following assumptions are made about these three factors as shown in Figure 21:

1. Population. We assume a very low growth rate, as given in the 1993 *Information Please Environmental Almanac* (0.0032% per year).
2. Per capita gross state product (GSP). Growth rate is obtained from extrapolating the GSP from 1980 to 1990; growth rate is 1.89% per year.
3. Energy/GSP. This is the energy intensity of the Illinois economy, which has been decreasing. We use three scenarios for continued decreasing energy intensity: –1% per year, –2% per year, and –3% per year. The first figure is relatively conservative, while –3% is at the outer edge of energy efficiency enthusiasts' projections (Bureau of Economic and Business Research 1992, U.S. Department of Energy, 1992).

As Figure 20 shows, the projections range from growth to a decrease in Illinois energy consumption. A

Table 5. Carbon content of fossil fuels.

Fuel (unit)	Carbon content in tons per unit	Carbon content in tons per million BTU
Coal (ton)	0.6050	0.0275
Oil (barrel)	0.1299	0.0224
Natural gas (thousand cu ft)	0.0163	0.0157

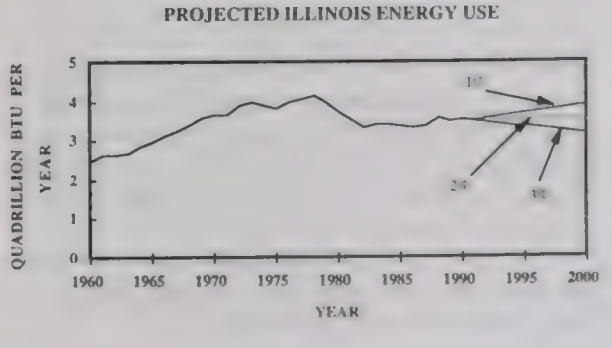

Figure 20. Several state energy use projections through the year 2000. Percentages refer to assumed annual change in energy/GSP.

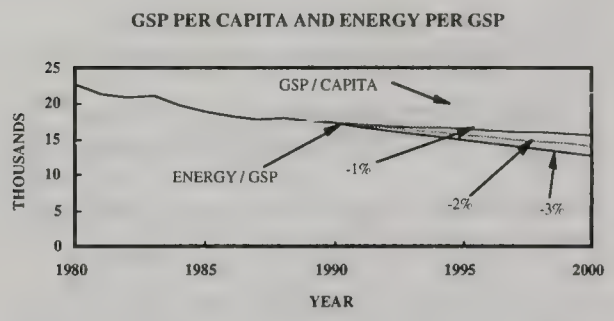

Figure 21. Assumptions for GSP/capita and energy/ GSP used in scenarios.

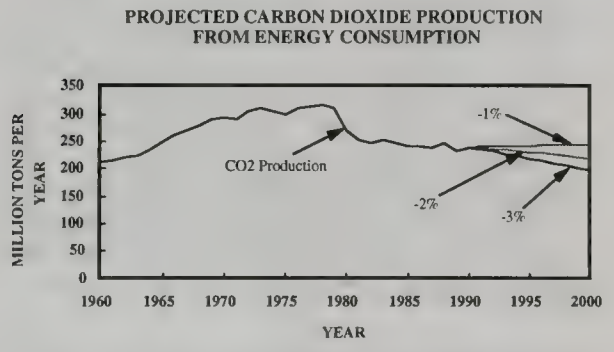

Figure 22. Projected carbon dioxide production in Illinois through the year 2000.

decrease will require energy per GSP to decrease faster than 2% per year if economic growth is equal to or greater than the projected 1% per year.

Given projected energy use, Figure 22 shows projections for Illinois CO_2 production through the year 2000. It is assumed that:

Total CO_2/yr = (CO_2 / energy) • (total energy use/yr)

The projections in Figure 22 range from a 0.08% increase per year to a 0.92% and 1.79% decrease per year in CO_2 production. It is important to note that if energy use increases over the next 10 years, the production of CO_2 will increase. This is due to the fact that nuclear power plants in the state are operating near capacity. Since no new nuclear plants are under construction or planned in Illinois, CO_2 per BTU will not continue to decrease as in 1980–1990, when nuclear plants came into operation.

RATIO OF FOSSIL TO SOLAR ENERGY

In addition to being a direct energy source for plant growth, the sun drives all biospheric processes and thus indirectly supports human activities through the environment's (1) production of fresh water, (2) production of a hospitable climate, and (3) absorption of our wastes, and so on.

A major goal of applied ecology and "ecological economics" is to evaluate this solar dependence and how it is altered by anthropogenic activities. Attempts at detailed quantification of the sun's role (such as H.T. Odum's EMERGY analysis [Odum and Arding 1991]) are not accepted (Mansson and McGlade 1993). However, there is justification for using the ratio of (fossil + hydro + nuclear energy) to insolation as an approximate indicator of environmental disruption and impact (Woodwell and Hall 1973, Smil 1991).

Annual average solar energy intensity in Illinois is essentially constant, varying only a few percent across the state. A graph of the annual amount of fossil energy consumed versus the amount of solar energy hitting the ground in Illinois is thus proportional to a graph of annual fossil energy consumption, which in Illinois actually decreased in the 1980s. Three points should be made:

1. Illinois' fossil to solar ratio was 0.06 in the late 1970s; that is, the fossil energy consumed was equal to 6% of direct solar input (Figure 23). The ratio dropped slightly in the 1980s but is now increasing again.
2. The entire world's fossil to solar ratio is about 0.0001 (1 in 10,000). It is 0.0084 in China and 0.11 in Germany. In Illinois, the fossil to solar ratio is

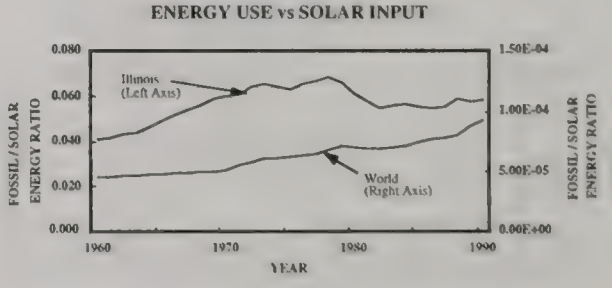

Figure 23. Ratio of fossil to solar energy for Illinois and the world, 1960–1990. Sources: Reinke 1993, U.S. Department of Energy 1992, World Resources Institute 1992.

therefore about 600 times that of the world as a whole, seven times that in China, and about 55% of that in Germany.

3. We lack data for determining the fossil energy/solar ratio regionally, but it is likely that the ratio is much higher than 0.06 in urban and suburban areas in Illinois. A very rough indicator of how much higher is offered by the data on transportation fuel consumption by county in volume 6 of this report (the volume on sources of environmental stress). Fuel use intensity (gallons per acre per year) in 1991 was:

Minimum	—	8.7	(Schuyler County)
Maximum	—	3091	(Cook County)
Average	—	153	(entire state)

Cook County's fuel use intensity was 20.2 times the average. If total energy use is proportional to transportation energy use, then Cook County's fossil to solar ratio is 20.2 x 0.06 = 1.2. Roughly speaking, therefore, for Illinois' most urbanized areas, the fossil to solar ratio is of order 1.

VEHICLES

The automobile, and vehicles in general, bring both benefits and environmental costs to Illinois. We include them as an indicator of environmental impact. Vehicles use 24% of Illinois' energy and produce 29% of Illinois' CO_2 (U.S. Department of Energy 1992). A part of critical trends analysis is therefore appropriately devoted to trends in vehicle use and their fuel-use efficiency.

Fuel-use efficiency for all vehicles hit a low of 10.83 miles per gallon in 1976 and then climbed to a high of 14.19 miles per gallon in 1982 in partial response to increasing federal new car fuel efficiency standards (Figure 24). From 1984 to 1990 fleet fuel efficiency dropped to 13.13 miles per gallon, in partial response to the reduced federal new car fuel efficiency standards.

Buses use substantially less fuel per passenger mile than cars. The number of buses in Illinois increased steadily from 1940 until 1980, but it has been dropping slowly since (Figure 25). Except for dips at the time of the Great Depression, World War II, and after the Iran-Iraq war of 1979–1980, the number of passenger cars has increased steadily since 1900. The trend is therefore toward more cars (the more energy intensive road passenger mode, average growth rate = 0.09% per year for 1980–1990) and fewer buses (the less energy intensive mode, average growth rate = –3.5% per year for 1980–1990).

Illinois' human population has been very nearly constant at 11.4 million since 1980 (average growth rate = 0.036% per year for 1980-90) (Figure 26). The

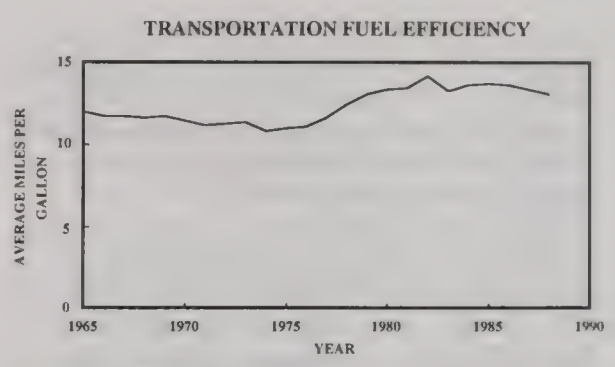

Figure 24. Fuel efficiency for all vehicles in Illinois, 1960–1990. Source: U.S. Department of Transportation 1980–1991.

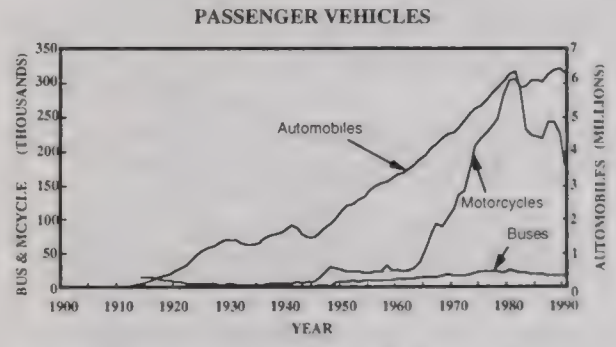

Figure 25. Cars, motorcycles and buses in Illinois, 1900-1990. In 1980-1990, cars increased 0.1% per year while buses decreased 3.5% per year. Source: U.S. Department of Transportation 1980–1991.

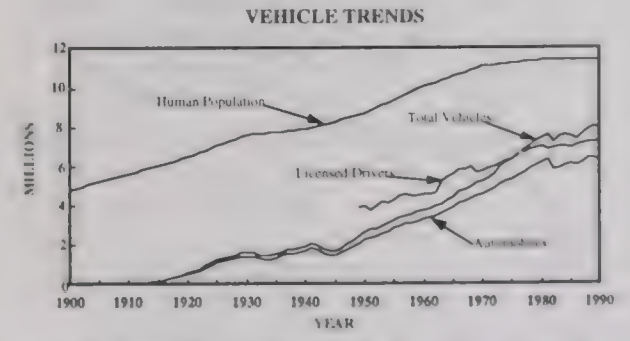

Figure 26. Trends in population, vehicles, cars, and licensed drivers, 1900–1960. Source: U.S. Department of Transportation 1980–1991.

number of cars, which rose about twice as fast as population in 1950–1980, has grown relatively little in 1980–1990, but the total number of road vehicles of all types has continued to grow. As the population "grays," the number of licensed drivers can be expected to increase even though population has stabilized (average growth rate for licensed drivers = 0.42% per year for 1980–1990).

Growth of cars/vehicles per capita and cars/vehicles per licensed driver, while slowing relative to the period 1950–1980, is still significant (Figure 27). There are currently (1990) 0.55 cars and 0.69 vehicles per capita. These figures grew at 0.094% per year and 0.49% per year, respectively, in 1980–1990.

Transportation fuel use grew steadily from 1950 to 1973, experienced a slight drop after the oil embargo of 1973, and then grew until experiencing a large dip (of 17%) in the 1980s, corresponding to the fuel price increases from the Iran-Iraq war (Figure 28). In the late 1980s the world price of oil dropped and transportation energy use climbed back to exceed its previous high. As state population grew only 0.0036% per year in 1980–1990, per capita transportation fuel use grew at 2.1% per year in that period. This reflects the steady growth of vehicles miles traveled in Illinois as described in volume 6 of this report (the volume on sources of environmental stress).

Figure 29 shows a projection of automobile registrations in Illinois to the year 2000. This projection (not prediction) combines assumptions about:

1. Population. Very low growth rate, as given in the 1993 Information Please Environmental Almanac (0.0036% / year).
2. Per capita auto registrations. Assumes arithmetic growth at the same rate as for 1980–1990 (0.094% / year).

RECYCLING

Total solid waste produced for the state in 1992 was 14 million tons (1.2 tons per capita, or 6.5 pounds per capita per day [World Resource Institute 1993]). As landfills fill and disposal fees increase, the need to find a place to put garbage becomes a serious issue to Illinois. A critical trend to monitor is how much waste is recycled.

Currently, the state of Illinois does not have complete data on how much is recycled per year at each recycling station. Figure 30 was generated using data collected from a survey (with voluntary response) of community recycling stations in Illinois conducted by the Illinois Environmental Protection Agency for the

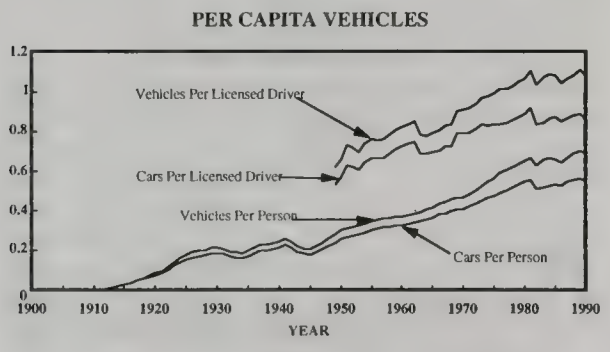

Figure 27. Per capita vehicles and cars in Illinois, 1950–1990. While their growth is slowing, both cars per capita and vehicles per capita are growing. Source: U.S. Department of Transportation 1980–1991.

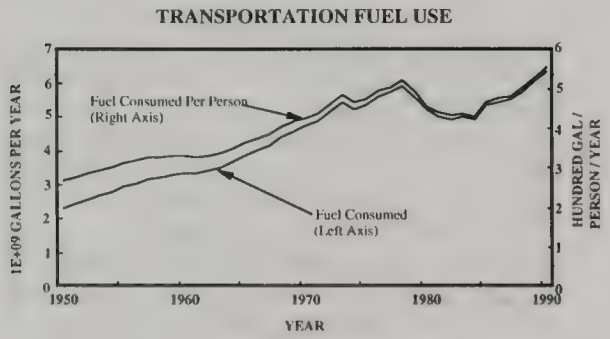

Figure 28. Per capita and total transportation fuel use in Illinois, 1950-1990. Source: U.S. Department of Transportation 1980–1991.

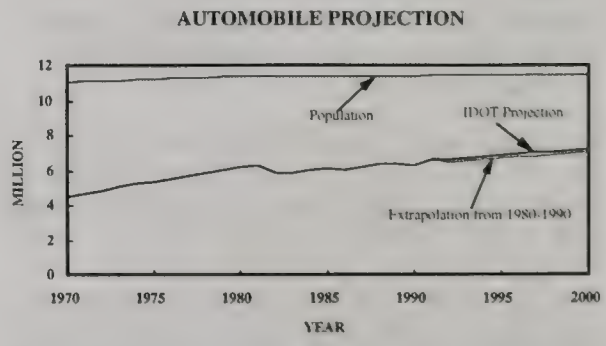

Figure 29. Projected human and automobile populations through the year 2000.

Table 6. Data from Illinois Environmental Protection Agency survey of Illinois recycling stations.

Year	# of surveys sent	% of surveys returned	Summed tons per year for responding stations	Average tons per year for responding stations
1989	329	29.9	852,211	8,094
1990	480	19.2	715,538	7,856
1991	480	31.1	1,665,065	10,840
1992	476	41.0	1,182,224	6,057

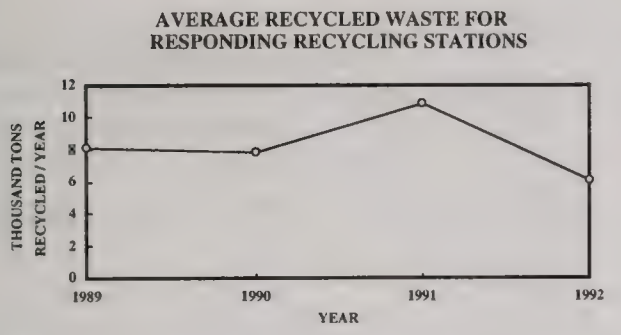

Figure 30. Average tons per year recycled for responding recycling centers. Data are incomplete; see text. Source: Illinois Environmental Protection Agency 1989–1991.

past 5 years (Illinois Environmental Protection Agency 1991). The figures are given in Table 6.

The average amount of recycled waste per year for responding stations is shown in Figure 30. This is likely a highly biased statistic, but it is the best available. No clear trend is evident. If we assume that Illinois solid waste production is about 5 lb per day per person, we can say that the totals in Table 6 are of the order of 8% of Illinois' solid waste production.

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16. Abstract (Limit: 200 words)

Illinois ecosystems are greatly affected by human activity. These effects are generally increasing, in spite of many improvements and a reduction in pollution sources. Often the largest impact is land use. Six ecosystem types are covered, and some general resource issues are analyzed. Prairies: Tallgrass prairie, which originally covered 60% of Illinois, is 99.99% gone. Forests: Once diminished by development, forests are coming back. Although many species use Illinois forests, biodiversity is threatened by forest fragmentation and introduced species. Agricultural Lands: Recent changes in farm practices have apparently lessened effects of agriculture on other ecosystems. Wetlands: About one-eighth of Illinois' original wetlands remain; wetlands are repositories of many threatened and endangered species. Lakes and Impoundments: Introduced species and fishing pressure have greatly affected Lake Michigan fish, and impoundments are seriously affected by sedimentation and eutrophication. Flowing Waters: Past declines in water quality led to extirpation or near-extirpation of many species. Conditions have improved, but sedimentation and chemicals continue to cause problems. Resource Analysis: Coal is the only energy source produced in Illinois for which reserves far exceed current consumption rates. The ratio of fossil fuel use to solar radiation in Illinois is 600 times the world average.

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